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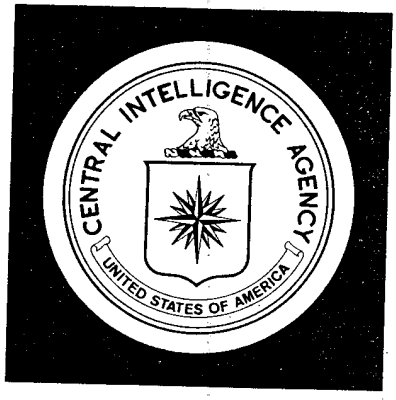

Research Aid

Ruble-Dollar Ratios for Construction

ER 76-10068
February 1976

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Ruble-Dollar Ratios for Construction

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CONTENTS

APPENDIXES

RUBLE-DOLLAR RATIOS FOR CONSTRUCTION

Summary and Conclusions

The ruble-dollar ratios computed in this study are based on cost estimates of construction projects in the United States and the Soviet Union. These estimates are fairly indicative of actual US costs (except military construction), but tend to understate costs in the Soviet construction industry, where overruns—averaging 20% of estimate costs—occur in more than 90% of all projects.

The 1970 ratios for aggregate construction are summarized below:

	Based on Estimate Costs	Adjusted for Probable Actual Costs
US-weighted	0.621	0.746
Soviet-weighted	0.539	0.647
Geometric average	0.579	0.695

These ratios permit a rough comparison of US and Soviet construction in 1970 as measured in rubles, dollars, and the geometric mean of the two price systems. Apart from possible definitional differences in the construction data, the results indicate that the value of Soviet construction was between 71% and 99% of US construction in 1970.

A comparison of construction projects by type reflects higher ruble-dollar ratios for industry and single-family housing than for service-oriented structures because the Soviet advantages of using standard plans and methods are not as readily applicable to industry and single-family housing. The relatively high ratios obtained for transportation construction projects are caused, in part, by the large degree of earthwork in which Soviet builders are less efficient.

Every effort has been made to guarantee that both the US and Soviet project samples are representative of construction in the respective country and that the project samples are truly comparable. Unfortunately, the conflicting nature of the criteria of representativeness and comparability and the limitations of the data probably have caused some understatement of the true ruble-dollar ratio.

DISCUSSION

I. Introduction

US-Soviet comparisons require the use of purchasing power parity (ruble-dollar) ratios. Construction price ratios are needed to compare output and productivity in a sector that is an important part of national product in both the United States and the USSR, is a key element of economic growth, and contributes a great deal to military programs in both countries. The ruble-dollar

ratios currently used in US Government studies are based on a 1964 CIA report, ER 64–26, *1955 Ruble-Dollar Ratios for Construction in the USSR and the US*, August 1964. These ratios have been moved forward each year with price indexes and are badly out of date.

The purpose of this study is to compute new ruble-dollar ratios based on costs in the two countries of a sample of construction projects representing as many fields of construction as the data permit. The definition of cost and the nature of the cost data are discussed in section II. Section III presents the sample of projects and discusses its representativeness in both countries. Section IV considers the comparability of the respective construction projects in the two countries. The final section presents the results and evaluates their reliability and probable bias in the light of deficiencies in the estimate cost data which are used. Appendix A presents the algebraic bases of these ratios, and Appendix B describes the techniques for deriving the average location in both countries. Appendixes C-H go into considerable detail about the methodology and results for each type of construction. Finally, Appendix I shows the computation of the US- and Soviet-weighted ruble-dollar ratios for all construction, both with and without an adjustment for Soviet cost overruns.

II. US and Soviet Data on Construction Costs

For purposes of this study, the cost of construction is defined as "the agreed selling price at which a completed project is (or would be) turned over to the investor."[1] The costs include the contractor's overhead and profits. Several kinds of expenditure that the investor generally considers to be a cost are excluded, however—for example, outlays for architectural and engineering fees, land, paving, walks, landscaping, caissons, piling, and moveable furnishings and equipment.

The first decision to make in a study such as this is how to define a unit of construction. Three approaches have been used in previous studies: construction inputs, construction components, and construction projects. We have selected the project approach as the unit of measure primarily because of the greater availability of data.[2] The costs of these projects in both the United States and Soviet Union are estimate costs. Theoretically, actual costs are preferable to estimates, but such data are seldom accessible in either country.

US Cost Data

The US data are obtained from three primary sources: *The Dodge Building Cost and Specification Digest* (hereafter referred to as *Dodge Digest*); *The Dodge Building Cost Calculator and Valuation Guide* (hereafter referred to as *Dodge Guide*); and *The 1972 Building Cost File/Eastern Edition* (hereafter referred to as *Building Cost File*). The *Dodge Digest* reports specific projects and winning bids. The building costs in the *Dodge Guide* are not actual ones, but rather estimates formed on the basis of construction parameters. The *Building Cost File* is used for transportation construction because the other two sources report

[1] CIA ER 64–26, *1955 Ruble-Dollar Ratios for Construction in the USSR and the US*, August 1964, p. 7.

[2] For a discussion of these three alternative approaches, see Norman M. Kaplan, "Some Methodological Notes on the Deflation of Construction," *Journal of the American Statistical Association*, September 1959, Vol 54, pp. 535–555.

nothing on this type of construction. Greater detail is provided about these sources in the appropriate appendixes.

Most of the US prices used in this study are winning bid or contractual prices from the *Dodge Digest*. In cases where bid or contract prices are unavailable, an engineering estimate is derived from various US construction costing handbooks. (These estimates also include allowances for profit and overhead.) All dollar amounts are adjusted to mid-1970 prices by construction cost indexes; the bid date is considered to be the starting time for the construction project for purposes of deflating costs to a 1970 base.

Soviet Cost Data

The proper price basis for comparing Soviet and US construction is the actual cost of completed projects, but these costs are hard to find for either country. In the United States, however, the contract bid price is not substantially different from the final price in private (non-governmental) purchases of construction.

For the USSR the data are far less accessible. The typical development of a construction project, according to both Soviet technical literature and private sources, is as follows. After a project is proposed, a design organization prepares a design and an estimated cost.[3] If the project is then approved and included in the economic plan, a construction organization is assigned to the project. In more than 90% of all projects, the construction organization finds that the initial cost estimate is too low. The design and estimate cost must then be revised. Typically, this is the first of many cost revisions in a sizable construction project.

The revisions reflect both real design changes and cost changes arising from overexpenditure of funds as compared with construction norms. These overexpenditures may occur as a result of higher-than-expected prices of materials, greater-than-expected difficulties, managerial inefficiency, inordinate delays, and the like. By and large, almost all of these costs are covered by successive revisions of cost estimates, so that at completion of the project the final cost estimate is near to the actual cost. If the final estimate is less than the actual cost, the difference is absorbed by the construction enterprise (from profits of other projects) or if necessary by the construction ministry involved.

The construction enterprises report the cost of work completed in final estimate prices in each reporting period. These reports, when summed by the Central Statistical Administration, are reported as the total value of construction in the USSR. Thus, final estimate costs apparently would be the proper and consistent prices for comparison with the announced total of construction activity. These costs are detailed initial engineering estimates amended by the actual construction cost experience.

Neither the initial cost estimates nor the final revised estimates with overruns included are available. The alternative of making detailed cost estimates from cost handbooks for a substantial number of projects is far beyond the resources available in this study. As a substitute, use was made of a set of handbooks (*sborniki*) that the Central Statistical Administration used in estimating the replacement cost of Soviet capital stock in the capital stock census of 1 January 1972 and 1973. The handbooks give simplified formulas for cost per

[3] *Estimated cost* in the Soviet context is defined as the cost of construction if the project were to be carried out strictly according to state norms and at established prices.

cubic meter for structures (a) designed for various purposes (for example, offices, hospitals, and warehouses); (b) of various specified sizes; (c) built with various construction methods and materials (for example, brick and block, steel frame, or reinforced concrete); and (d) situated in various locations (for example, remoteness of material supplies and climate).

The editions of these handbooks have been published sporadically since 1970, and the costs, which are based on the prices introduced on 1 January 1969, are assumed to be 1970 prices. These series are published in multivolume editions which bear the formal titles: *K sbornikam ukrupnennykh pokazateley vosstanovitel'noy stoimosti zdaniy i sooruzheniy dlya pereotsenki osnovnykh fondov* (Handbooks of Consolidated Indices of the Replacement Cost of Buildings and Structures for the Revaluation of the Fixed Capital Stock) and *K sbornikam ukrupnennykh pokazateley vosstanovitel'noy stoimosti zdaniy i sooruzheniy, imeyushchikhsya v uchrezhdeniyakh i organizatsiyakh, sostoyashchikh na gosudarstvennom byudzhete* (Handbooks of Consolidated Indices of the Replacement Costs of Buildings and Structures in the Institutions and Organizations Included in the State Budget). When individual citations are needed, these books are referred to as *Sborniki, Investment Series,* and *Sborniki, Budget Series,* respectively, but are collectively called *Sborniki.*

III. Representativeness of the Sample

The projects to be costed must be selected so that the samples represent each country's construction patterns. The problem is to establish criteria for deciding whether the samples collected are representative. Four criteria of representativeness are: project function, location, size, and construction characteristics. The construction projects used in this study do not satisfy all of these criteria, but we have tried to minimize the problems involved.

The ruble-dollar ratios for construction are based on a sample of 277 projects representing a broad cross section of construction. These observations have been grouped according to project function and ratios computed for each group (see the appendixes for a detailed description of the sample and results, category by category). This sample is described in the following manner:

Type of Project	Number of Observations	Percent of Total Observations
Hospitals	51	18.4
Housing	69	24.9
Office buildings	58	20.9
Schools	53	19.1
Industrial facilities	32	11.6
Roads	4	1.5
Airfields	5	1.8
Railroads	5	1.8
Total	**277**	

Functional Representativeness

To represent construction from the standpoint of function, the categories of construction for which ruble-dollar ratios are computed in this study should

mesh with the categories used in each country's published aggregate data. Moreover, within each category the construction projects selected for the sample should be representative of that category. There are major deficiencies arising from unavailability of data. The importance of the deficiencies is discussed below.

The US Department of Commerce publishes statistics of new construction put in place by type of project—residential, industrial, commercial, religious, hospital, educational, military, road, railroad, communications, power, and sundry types of water resource projects. The ratios computed in this study can be matched to construction categories representing 74% of US construction. The neglected categories include the following [4]:

Category	Share of Total Value of Construction in 1970 (Percent)
Total	**25.7**
Religious buildings	1.0
Nonresidential agricultural construction	0.9
Telephone and telegraph construction	3.2
Electric light and power construction	6.2
Gas construction	1.7
Petroleum pipelines	0.2
Military facilities	0.8
Conservation and development	2.0
Sewer systems	1.6
Water supply facilities	1.2
Other public buildings	2.8
Miscellaneous public construction	2.2
Miscellaneous private nonresidential building	0.9
Residual private construction	1.0

The ruble-dollar ratios for the omitted US construction categories probably are not far different from the ratios computed for the categories represented in the sample. Religious buildings are excluded because churches are not currently being built in the Soviet Union. Telephone and telegraph construction contains items such as exchange buildings, office buildings, maintenance buildings, repeater stations for microwave, microwave towers, telephone line construction, etc. We believe that the ratios for this construction, except perhaps microwave facilities and telephone line construction, lie within the range of the industrial construction ratios. Considering the relatively greater US sophistication in communications technology, the ruble-dollar ratio for the above exceptions would probably be higher than for the rest of the sample. Fortunately, this type of project has a small weight in US construction.

Electric light and power construction contains items such as all types of powerplants, transmission lines, dams, cooling towers, and reservoirs.[5] Most of the projects included in this sector are similar to industrial or highway construction. Petroleum-related construction contains industrial-type work such as pipelines, wells, pumping stations, and gas production, distribution, and storage facilities.

[4] US Department of Commerce, Domestic and International Business Administration, Bureau of Competitive Assessment and Business Policy, *Construction Review*, May 1973, pp. 10–11.

[5] A few thermal powerplants were compared in a rough manner. The tentative results suggest the ratios for thermal powerplants lie within the range of the industrial ratios.

Construction of military facilities contains a potpourri—airfields, roads, housing, missile silos, and industrial facilities. Conservation and development construction contains projects such as erosion control schemes and irrigation facilities. Costing this type of construction is difficult, but it is unlikely that the resulting ruble-dollar ratios would be grossly atypical of other construction. We omit sewer systems and water supply facilities from the sample because of the problems involved in identifying comparable Soviet and US items.

How representative the samples are of Soviet construction is difficult to determine. Aggregative Soviet construction data arranged by function are published only when combined with other types of investment—e.g., investment in machinery. Thus, functional weights for construction and installation work,[6] which in 1970 amounted to approximately 61% of Soviet investment, must be independently estimated as is described in Section V.

We estimate that the sample categories provide good coverage of Soviet construction except for agricultural construction and construction within the construction industry itself. These omitted sectors, however, constituted about 19% of Soviet construction in 1970.

Nonetheless, their ratios probably are not atypical. Construction performed for the construction industry is similar to some industrial construction in that it includes structures such as warehouses, garages, sheds, and the like. Hence, ratios for this construction should lie within the range of the ratios already computed. The USSR publishes data on four categories of agricultural investment, although not solely for construction. The livestock raising category, which constituted approximately 4% of Soviet investment in 1970, contains construction of barns, silos, and grain storage facilities. These ratios probably are similar to the industrial ratios because they reflect similar types of structures. The water resources category of investment (3.7% of 1970 investment) includes projects such as dams, canals, and pumping stations. These ratios are likely to be akin to the ruble-dollar ratios for road construction because they both require large quantities of earthmoving work and concrete laying activity. A third category of farm investment—electrification—represents less than 1% of Soviet investment and probably is even less significant in Soviet construction activity because such investment has an especially high equipment content. The fourth category of agricultural construction includes the establishment of gardens, vineyards, and other perennial plantings; it was only 0.5% of 1970 investment and is not taken into account.

Representativeness of Location

Location cannot be ignored in ruble-dollar ratio studies because it helps to determine both the utility and cost of a project. There is no national market for construction as there is for many manufactured products; instead, a nation's construction industry is a composite of many local and regional markets.

These decentralized markets are a result of imperfection and immobility in both input and product markets. For example, construction materials are frequently produced and consumed in local markets because transportation costs represent a large percentage of value. Labor costs vary regionally by

[6] Soviet investment data almost always lump the cost of construction and installation work together. Henceforth, when we speak of official Soviet statistics, the word *construction* is our abbreviation for construction and installation work. It is important to stress, however, that the estimate costs derived from the *Sborniki* exclude the value of installation work.

substantial amounts because of the degree of unionization and because of the refusal of workers to move from their homes to a location where wages are more lucrative. Climate is another variable explaining regional differences. Finally, when a building is constructed, it usually cannot be transported to another location where it provides greater utility.

Ideally, the way to obtain a locationally representative ratio is to place the whole construction sample for each country at a place where the costs are average for that country, and this is what we have tried to do. (For a description of the procedure, see Appendix B.) As long as observed cost variations within each country are purely the result of different input prices, there is no problem in comparing average prices. The use of average building costs in each country may cause the projects to lose some comparability in ways undetected by the coarse parameters of the data. For example, the average climate in the USSR is harsher than our own, and buildings erected in Siberia might contain more insulation and embody other minor structural changes to better withstand the climatic rigors in ways which would influence costs. It is difficult to discriminate between the regional variations explained by physical differences in construction and those that are merely a result of different input prices. However, since other sources of bias in this study—e.g., differences in quality between US and Soviet construction—run in the opposite direction (that is, they lead to an underestimate of the ratio), it would represent an offsetting error.

Representativeness of Project Sizes

Within the sample, projects should be representative in terms of size to the extent that the ruble-dollar ratio is a function of project size. This study does not ensure that samples containing representative project sizes are collected. Two approaches are used to deal with project size within many of the functional categories of construction. One approach employed in defining a US-weighted sample uses a quasi-random sample of projects from US construction. This results in a distribution fairly characteristic of US sizes, although some larger projects have had to be excluded because of the absence of a Soviet counterpart.

In contrast, the second approach, which attempts to use a sample representative of Soviet construction for computing dollar-ruble ratios based on Soviet weights, considers the size phenomenon by creating a sample stratified by size as measured by the number of stories. Purchasing power parity ratios are computed for both the largest and smallest possible physical construction volumes for a structure with a given number of stories. Subsequently, the average of these two ratios is accepted as the ratio for that type of construction. Although this procedure is imperfect, the amount of error should be small if the ruble-dollar ratio varies with size in an approximately linear fashion. Not much more can be done to eliminate this methodological deficiency in the Soviet sample because the size distribution of construction projects is unknown.

Representativeness with Respect to Physical Aspects

To be representative, projects in the sample should reflect typical physical characteristics in terms of inputs, components, and technical specifications. In this respect, for example, a typical Soviet building would probably have five stories, a concrete exterior, a concrete frame system with a minimum of steel, and no elevators or air-conditioning. A typical US building would probably be taller, with a steel frame structural system, brick walls, elevators, and air-

conditioning. Obviously, such extreme differences make it impossible to compare a completely typical Soviet building with a typical US building and yet maintain complete comparability. As a result, the need arises to trade-off between these dual requirements—i.e., comparability and representativeness in studies of construction ruble-dollar ratios.

In the approach based on a quasi-random sample of US construction, a sample fairly representative of US construction has been derived. Another approach forms a stratified sample of either Soviet or US construction by computing ruble-dollar ratios for various structural categories—for example, grouped by number of stories or the presence or absence of elevators—and then averages these ratios by the use of weights based on estimated construction values.

The sampling procedure in this study excludes US construction projects that have no Soviet counterpart and Soviet construction projects that do not have a US counterpart. The US construction excluded by this procedure is generally ornate and luxurious; the omitted Soviet projects are usually primitive, lacking in social amenities, or made from materials unique to the USSR. The value of Soviet construction unrepresented in the samples probably has diminished in importance over time, but the excluded US construction probably is growing more important.

In summary, the criteria for a representative construction sample are difficult to satisfy precisely. In selecting a sample, we have concentrated on function, location, size, and physical characteristics. The procedures we have used are shaped in important ways by the data that are available. The sample appears to represent US construction quite well and Soviet construction less well.

IV. Comparability of US and Soviet Projects

In addition to being reasonably representative of construction in each country, the construction sample should be selected so as to ensure comparability between the US and Soviet projects included in the sample. The need for comparability covers six criteria: function, size, structural type, inclusion of amenities, quality of work, and aesthetics. Although this study has tried to deal with the first four of these aspects, the remaining two—quality and aesthetics—are much more difficult to handle.

Functional Comparability

To be comparable functionally, the projects compared should be used for the same purpose. For example, American schools are compared with their Soviet counterparts. Occasionally, a problem may arise about the appropriate breadth of *function*. For example, should the function of schools be defined as "a building in which educational activity occurs," or should a distinction be made between primary and secondary educational facilities? Questions like this have had to be resolved on an *ad hoc* basis.

Size Comparability

A second aspect of project comparability pertains to the size of the projects being compared. Size could be measured by the project's output capacity or by its physical size. In other words, we could compare projects that provide the same volume of goods or services, regardless of construction differences, or we could compare projects that occupy the same physical space as measured by volume, area, or length.

Physical dimensions rather than output capacities are the standard of comparability in this study for both pragmatic and theoretical reasons. Data on construction volume are much more readily available than capacity data, and the concept of plant capacity is often too nebulous to define precisely in any event. Moreover, capacity differences between two buildings identical in construction often result from different equipment and methods of operation. For example, a Soviet plant generally has less productive potential than its US counterpart of the same size because of inept management, less productive labor, and inferior machinery.

Structural Comparability

According to the third criterion of project comparability, the types of construction should be comparable where possible. Hence, major structural components, such as foundations, frames, roofs, and the like, should be equivalent. In most cases the data are too limited to permit complete adherence to this principle, but where possible we sought to achieve equivalency. For example, a Soviet school made with bricks is compared with a like US school. In cases where complete material comparability is lacking, the closest substitute was selected. In some cases the construction method costing the least may be different in the two countries (i.e., brick in the United States versus precast concrete in the USSR). If no suitable substitute exists, the project was not used in the sample. As two buildings are examined in more detail, many physical differences become readily apparent, but the data on which the cost estimates are based, both in the United States and the USSR, are not sufficiently detailed to permit precise comparison.

Amenities

The fourth criterion of project comparability stipulates that the two projects should possess the same utilities and conveniences, such as heating, air-conditioning, electricity, plumbing, and built-in equipment. These items may collectively be referred to as amenities. A problem arises because Soviet and American practices differ with respect to amenities. For example, few Soviet buildings have air-conditioning, and few new American buildings lack it. Construction specifically intended for human occupancy—hospitals, apartments, offices, and schools—contains more amenities than facilities designed for industrial and transportation purposes. Therefore, the differential for amenities between the United States and the USSR is probably largest for the service-oriented structures and lowest for transportation and industrial construction.

Many amenities are small items, but taken together they may add greatly to a project's final cost. For example, Soviet apartments have fewer electrical outlets, kitchen facilities, and miscellaneous amenities than their US counterparts. These minor differences cannot be quantified in the cost comparisons, because data disaggregated to the necessary extent are seldom available.

Two types of amenities, built-in equipment and air-conditioning, have been singled out for special treatment. In most of the US data, expenditures for built-in equipment are separable and are removed to enhance the comparability with Soviet construction. US data on the percentage of total cost represented by air-conditioning for a certain type of building are available in a limited number of cases. The average percentage for each building type is assumed as the standard air-conditioning component in all similar buildings and the costs are reduced

accordingly to remove the air-conditioning. This correction is discussed individually by construction sector in the appendixes. In theory, this approach only goes halfway in the treatment of the problem. The Soviet buildings should also be costed with air-conditioning and the built-in equipment in order to make them comparable to the more elaborate US counterparts, but this procedure is impossible with existing data.

Quality Comparability

The fifth aspect of comparability focuses on the quality of work and what quality implies for subsequent maintenance outlays. There can be no doubt that the quality of the average Soviet structure is inferior to that of the average US structure. Not all of these qualitative differences imply, however, that the lifespan of a structure is necessarily shorter or that the utility provided by the project is diminished. Many of the apparent incomparabilities affect only appearance and reflect what each culture is willing to tolerate.

Not all these quality differences are even directly attributable to the construction process itself, but instead reflect a different attitude toward maintenance expenditures. There exists a trade-off between construction and maintenance costs. For example, an inferior paint job during construction means the walls must be repainted sooner than if the original job had been thorough. Shoddy electrical wiring during construction means the wiring must eventually be ripped out and re-installed later at a greater cost. The poor quality of Soviet construction suggests that a portion of maintenance costs should really be allocated to construction costs to permit valid comparisons.

Qualitative problems of comparability are difficult to handle empirically. The best we could do was to arrange the comparisons so that the highest quality Soviet construction was compared with average and poor quality US construction. Although this procedure is quite arbitrary and does not really eliminate the problems, at least the correction moves in the proper direction.

Aesthetic Comparability

Aesthetic appeal also affects comparability. An attractive building provides more social utility than an ugly one; an attractive factory may even increase worker productivity by improving morale. Unfortunately, this factor cannot be considered in a study of this nature, because aesthetics cannot be quantified.

V. Empirical Results

Value Weights for the Aggregate Construction Ratio

As mentioned earlier, US value weights for different types of construction rely on the reported value of construction put in place as published by the Department of Commerce. Corresponding ruble-dollar ratios could be matched with 74% of the value of construction reported in 1970, although some problems were encountered. For example, the computed ratio for hospital construction is probably distorted and unacceptable, as discussed later, so it has been replaced by the geometric mean of the ratios for housing, office building, and school construction. Also, we were unable to determine an independent weight for the ruble-dollar ratio for airfield construction. Yet another problem was that the commercial category reported by the Department of Commerce includes other commercial buildings in addition to office buildings—e.g., stores and restau-

rants—but we have assumed that the ruble-dollar ratio for this other commercial construction is equivalent to the ratio for office buildings.

Considering these difficulties, the US weights are presented below:

Category of Construction	Weight
Hospitals	0.048
Housing	0.471
Commercial	0.140
Schools	0.093
Industry	0.101
Highways and streets	0.143
Railroads	0.004

The Soviet value weights must be derived in an indirect manner because of the general absence of construction data based on a functional distribution. Even the category closest to construction—i.e., the capital investment data—is disaggregated into only seven rather gross classifications: (1) industry, (2) agriculture, (3) transportation and communications except railroads, (4) railroad transport, (5) construction industry, (6) housing construction, and (7) construction of trade and communal enterprises, forestry enterprises, and institutions of science, culture, art, education, and health. Additional sources permit an estimate of the amount of construction and installation work for all of these categories except categories 6 and 7. They are estimated by computing the residual of total construction minus the estimated value of construction for the other five sectors displayed in the capital investment data. By using the residual and the reported capital investment for these two sectors, an estimated proportion of construction to capital investment is derived by assuming that this proportion is equal for both residual categories. The derivation of these weights is given in Table 1.

Unfortunately, these categories fail to mesh exactly with the ruble-dollar ratios computed in this study, so allowances must be made. The industry, railroad transport, and housing construction sectors match up well with the ratios. The composition of the transportation and communications other than railroads, however, is rather murky, so we have arbitrarily assigned the geometric mean of the ratios for construction of roads and airfields to this category. The trade and communal enterprises category is equally imprecise. Presumably, construction in that category is largely schools, office buildings, hospitals, and stores. Arbitrarily, we have assumed the appropriate ratio for this category is the geometric mean of the ratios for office buildings and schools. We would have included hospitals too, but as discussed later, we reject the hospital ratios because of problems in attaining true comparability.

Unadjusted Computations

Ruble-dollar ratios calculated for eight major categories of construction and the weighted ratio for all construction appear in Table 2. (For specific findings relating to each category of construction, see the appropriate appendix, and for derivation of the aggregate ratio, see Appendix I.) For some types of construction, the methodology and available data permit estimating both a US and Soviet value-weighted ratio. By a weighted ratio, we mean that a sample of

Table 1

Derivation of Soviet 1970 Construction Weights

(1)	(2) Capital Investment (Billion Rubles)[1]	(3) Share of Investment by Construction and Installation (Percent)[2]	(4) Construction and Installation (Billion Rubles)[3]	(5) Share of Construction and Installation by Function (Percent)[4]	(6) Weight of Construction and Installation by Function (Percent)[5]
Total	**82.053**	**61**	**50.298**	**100.0**	**100.0**
Industry	29.567	50	14.784	29.4	36.2
Agriculture	14.152	60	8.491	16.9	....
Transportation and communications except railroad	5.494	45	2.472	4.9	6.0
Railroad transport	2.314	45	1.041	2.1	2.6
Construction industry	3.008	31.3	0.942	1.9	....
Housing construction	13.439	82	11.022	21.9	27.0
Construction of trade and communal enterprises, forestry enterprises, and institutions of science, culture, art, education, and health	14.079	82	11.545	22.9	28.2

[1] *Narodnoye khozyaystvo SSSR 1922–1972*, pp. 326-327.

[2] The share of investment allocated to construction and installation work for industry, agriculture, and transport and communications is obtained from *Statisticheskiy yezhegodnik stran-chlenov soveta ekonomicheskoy vzaimopomoshchi 1973*, pp. 172–179. It is assumed that the shares for railroad transport and all other transport and communication are identical so an additional category may be used. The estimated share for investment in the construction industry is based on data for the 1966–70 period from V. D. Belkin, *Ekonomicheskiye izmereniya i planirovaniye*, p. 205. The share for housing and the enterprises and institutions category is obtained as a residual of unallocated construction in column (4) and by assuming that both categories have the same share devoted to construction.

[3] For all categories except the last two, the entry represents the product of column (2) and column (3). The last two items are residuals to allocate remaining construction within the constraints of the control total derived from *Narodnoye khozyaystvo SSSR, 1922–1972*.

[4] Column (4) ÷ 50.298.

[5] Column (5) ÷ 81.2. This reallocates the weights so they sum to 100.

Table 2

Summary of Ruble-Dollar Ratios by Type of Construction

Type of Construction	US-Weighted Ratio	Soviet-Weighted Ratio	Geometric Mean Ratio
Hospitals	0.347	0.276	0.309
Housing	0.620	0.494	0.553
Single-family	N.A.	N.A.	0.646
Multi-family	0.586	0.454	0.516
Office buildings	0.508	0.451	0.479
Schools	0.583	0.501	0.540
Elementary	0.552	0.485	0.517
Intermediate	0.617	0.518	0.565
Industry	N.A.	N.A.	0.601
Light	N.A.	N.A.	0.628
Heavy	N.A.	N.A.	0.576
Roads	N.A.	N.A.	0.790
Airfields	N.A.	N.A.	0.695
Railroads	N.A.	N.A.	0.836
Aggregate construction	0.621	0.539	0.579

individual project ratios is combined in such a way that it is representative of the construction of that type in the country and serves as the source of weights.

The most obvious observation from Table 2 is that, in every case where a distinction is possible, the Soviet-weighted ratio is less than the equivalent US-weighted one.[7] This accords with the theory that a country has a relative advantage in producing its own mix of output. As a result, in international comparisons there is a frequently observed negative correlation between relative prices and quantities.

Of the ratios presented in Table 2, the railroad ratio is the highest and the hospital ratio the lowest. The railroad ratio makes sense because railroad construction requires a great deal of earthwork in which the Soviets are at a relative disadvantage. Furthermore, the Soviet construction industry uses steel much less intensively than its US counterpart. On the other hand, we do not use the hospital ratio for what we believe are compelling reasons.

Discussions with architects suggest the comparability problem is particularly severe in hospital construction and that the comparisons in this study suffer from it. The United States has experienced a technological revolution in hospital design in the past 10 to 20 years. The USSR has failed to keep pace with this and now lags behind the United States by more than 10 years.

For example, US hospitals have sophisticated equipment and delivery systems—food, medicines, laundry, oxygen, etc.—that are conceptually inseparable from the structure itself. These systems are frequently stored in what is nearly a full floor between floors called interstitial space, so that a five-story hospital may really be comparable to a ten-story building. Interstitial space affects both construction costs and maintenance costs, raising the prior and lowering the latter. Meanwhile, this concept is hardly known in the USSR, where their hospitals often lack even crawl space.

Part of these differences in US and Soviet hospitals is explained by different levels of knowledge; another part reflects different rates of substitution between labor and machinery in operating a hospital, with the Soviets utilizing a lower capital-labor ratio. Nevertheless, these technological differences are apparently not avoided by removing the cost of built-in equipment from the US hospitals as we have done.

Thus, in computing the US-weighted ruble-dollar ratio for construction, we used the geometric mean of the US-weighted ratios for housing, office buildings, and schools in place of the discredited hospital ratio. We suspect that once a sample of truly comparable Soviet and US hospitals stripped of equipment is formed, the ratio would probably not vary much from other service-oriented structures. Using the actually computed hospital ratio—0.347—instead of the substitute—0.568—would have lowered the aggregate ratio from 0.621 to 0.611.

Ruble-dollar ratios for industrial facilities are higher than the ratios for service-oriented structures other than single-family housing. Service-oriented buildings are more homogeneous in the USSR than in the United States because Soviet plans are more standardized. The construction of standardized facilities in turn permits realization of substantial cost economies. For example, the standard plans for service-oriented structures permit a high degree of prefabrica-

[7] This relationship, called the Engel-Gerschenkron effect, is not inevitable, as Samuelson points out in the "Analytical Note on International Real-Income Measures," *The Economic Journal*, September 1974, pp. 595–608.

tion of construction components, a practice the Soviets frequently refer to as the "industrialization of construction." This industrialization is practical only as long as construction output is in standardized components.

Industrial construction, on the other hand, does not adapt as well to the use of standardized forms and components, because factories are by nature more heterogeneous than service-oriented construction. Also, the Soviet construction industry is fraught with many difficulties and inefficiencies in the planning and actual execution of construction. To a certain extent, these problems which impact on cost are less pervasive when the same type or a similar project is built over and over. Therefore, these potential cost savings are not garnered in industrial construction as they are in the more repetitive service-oriented construction; as a result the ruble-dollar ratio for industrial construction is larger than for service-oriented structures.

Ratios for transportation construction also exceed the ratios for service-oriented facilities. Construction of transportation projects and of buildings is fundamentally different. Typically, US construction firms specialize in either category, but not both. Transportation construction requires fundamentally different machinery and technology. Also, it is potentially more capital-intensive than other construction, so greater economies of scale can be realized. A US construction organization typically has more equipment at its disposal than its Soviet counterpart. Moreover, Soviet construction machinery is typically smaller and less productive than US counterparts. All these factors permit the US construction industry relatively greater efficiency in building transportation projects than in service-oriented structures.

Adjusting the 1955 ruble-dollar ratios computed in the previously cited CIA study to a 1970 base by deflating for both Soviet and US price changes permits a comparison of the relative productivity changes in construction during the period 1955–70 (see Table 3). The aggregate construction ratio increased by nearly 14% over this period, suggesting that, despite the rampant inflation in the US construction industry, its productivity has increased more rapidly than that of its Soviet counterpart. The number of observations in the earlier study

Table 3

Comparison of 1955 and 1970 Ratios

	1970 Ruble-Dollar Ratios	1955 Ruble-Dollar Ratios [1]	1955 Ratios Updated to 1970 Prices via Price Indexes [2]
Hospitals	0.31	....	....
Housing	0.55	0.66	0.48
Office buildings	0.48	0.60	0.44
Schools	0.54	....	....
Industry	0.60	0.74	0.54
Roads	0.79	1.00	0.73
Airfields	0.70	1.02	0.75
Railroad	0.84	0.78	0.57
Aggregate	0.58	0.70	0.51

[1] CIA ER 64-26, *1955 Ruble-Dollar Ratios for Construction in the USSR and the US*, August 1964.

[2] In 1967, Soviet construction and installation work equaled 33.6 billion rubles in 1955 prices and 41.5 billion rubles in 1969 prices, or an increase of 23.5%. The Department of Commerce *Composite Cost Index* grew 68.9% during the period 1955–70.

is too limited, however, to permit meaningful conclusions to be drawn regarding specific types of construction, except that in all categories except airfields the adjusted 1955 ratio is less than the corresponding current one.

Several explanations can be offered for this decrease in Soviet efficiency relative to the US. Rapidly escalating wages for US construction labor have stimulated contractors to substitute capital (i.e., construction machinery) for labor. Meanwhile, the Soviet construction labor force remains substantially less productive than its US counterpart and suffers from a chronic shortage of skilled labor. Soviet labor's cheapness relative to capital, however, precludes much substitution of capital for labor. Even when the substitution is made, the results are frequently unsatisfactory. Unless the construction machinery is imported, which has been the case for use on important projects, the machinery has less capacity than its Western counterpart and is unreliable. Shortages of both spare parts and the mechanics necessary to repair and maintain the equipment also add to the difficulties of capital-labor substitution.

Adjustment of the Ratios

The ruble costs used in this study are estimated costs derived from the *Sborniki*. Two questions must be answered in determining whether use of these costs is permissible. First, the relationship between these *Sborniki* costs and the detailed estimate costs, the first revised estimate that construction enterprises provide themselves at the beginning of a project, must be determined. Second, the relationship between the first revised estimates and actual costs must be considered. Unfortunately, the evidence for these two comparisons is fragmentary at best.

Moreover, the Soviet distinction between standard (*tipovoy*) and nonstandard (*individual'nyy*) project designs is important. Standard designs are those already completed and approved by the state and are recommended for use where possible. They represent minimum cost and quality and are designed to capture the maximum economies of scale. Standard designs are available for almost any kind of structure. According to one Soviet investment specialist, they were used in recent years in structures representing 81% of the overall volume of construction, including 97% in housing construction, 68% in industrial construction, 87% in cultural and service construction, 88% in transport construction, and 95% in agricultural construction.[8] However, other sources say that standard construction is used predominantly only in apartment construction (but even in apartment buildings, that may not apply for enterprise-sponsored housing or most cooperative housing). In industry, these other sources state that standard designs are seldom used, although the use of standard design components for many structures perhaps explains the allegation that 68% of industrial construction is of standard design.

The difference in cost that the use of standard and nonstandard construction can make is impressive. A source familiar with urban construction performance states that nonstandard construction of apartments or other urban

[8] V. P. Krasovskiy, "The Investment Process and How to Improve It," *Ekonomika i organizatsiya promyshlennogo proizvodstva*, No. 1, 1975. Also in JPRS 65240, *Economic Affairs*, 16 July 1975.

cultural or commercial buildings is frequently two and one-half to three times more expensive than construction based on standard designs. In part, this is due to real design changes, which would also be more expensive in the United States. But the higher cost also is due partly to higher prices and lower productivity. Industrial construction may be worse in this respect. The implication is that a comparison of the costs of nonstandard design for a given structure in the USSR with costs of a comparable structure in the United States would be substantially less favorable to the USSR than a comparison based on costs of standard designs.

The question of the validity of *Sborniki* costs as a measure of estimated costs seems to have been answered in an article by Yu. I. Malimanov of the State Committee of the Council of Ministries of the USSR for Construction Matters (Gosstroy).[9] The *Sborniki* supposedly are based on consolidated estimating norms. These consolidated norms were developed to determine the construction cost of buildings and structures that are individually designed but with "standard design solutions and standard structure and members." During the development of these consolidated estimating norms, Gosstroy compared the consolidated estimates with estimates derived from the standard price handbooks. Gosstroy approved only the consolidated estimates as norms if the deviations from the price handbook estimate were less than 2%. For this reason, the *Sborniki* costs probably lie fairly close to the detailed estimate costs.

As for the relation between the detailed estimate cost and actual costs, the ubiquity and size of construction cost overruns are the subject of endless tirades by Soviet economists and planners. For example, Krasovskiy says:

> . . . making use of the current system of estimated funds, capital construction in essence has what may be termed an open bank account and, without any great difficulties, can exceed the initial project costs by 1.5 to two or even four times. No similar situation exists in any other sector of material production in the Soviet Union.[10]

But remembering that an initial revision of estimate cost frequently is required to correct a deliberately and unrealistically low cost design, we should discount the upper end of the range of overruns given above. Krasovskiy [11] cites an estimate by the USSR Construction Bank that estimate costs rise 10% every year (for given projects). Thus a large-scale project that takes eight years to complete may have cost 43% more than the initial working estimate.[12] This slippage is

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[9] Yu. I. Malimanov, "Improve Estimating and Price Setting in Construction," *Ekonomika stroitel'stva,* No. 4, 1975, pp. 3–10.

[10] Krasovskiy, *op. cit.*

[11] *Ibid.*

[12] Assume equal annual amounts of construction as measured by physical volume of work—i.e., 12.5% per year.

Let: P = the total cost of the project;
I = the annual rate of increase in estimates; and
t = the number of the year.

Thus, the true cost of the project will be:

$$P = \sum_{t=0}^{7} 0.125\ I^{t}$$

Where there is no "inflation"—i.e., I = 1.0—the cost of the project equals unity (the original estimate cost). Where estimates creep up yearly, the total cost is 1.429, or (0.125 + 0.138 + 0.151 + 0.166 + 0.183 + 0.201 + 0.221 + 0.244).

all the more critical because of the notoriously slow pace of Soviet construction. According to Krasovskiy,

> In the Ninth Five-Year Plan the construction period took about twice as long as the normative called for. . . . In turn, our normatives call for about twice as long as the actual timespan abroad.

Cost overruns are more prevalent and larger in nonstandard design construction. Since the *Sborniki* are intended for standard construction, they are especially deficient in handling cost overruns. A private source has estimated that nonstandard office buildings typically experience cost overruns of about 20%–30%.

We conclude from this testimony that the costs estimated from the *Sborniki* must be rather arbitrarily adjusted upward. Some fragmentary evidence concerning the approximate magnitude of the upward adjustment suggests some upper and lower bounds. On the low side, a recent article states, "The formulation of the draft 1973 plan revealed that cost overruns for leftover construction projects based on the USSR Gosplan totaled 8 billion rubles." [13] There are at least three plausible interpretations to this rather cryptic statement. One, cost overruns explain 8 billion rubles or 12% of unfinished construction.[14] An alternate interpretation is that the 8 billion rubles should be compared with that year's planned unfinished construction—51 billion rubles.[15] This would suggest that actual costs exceed estimate costs by nearly 16%. Third, the 8 billion rubles could be interpreted as the cost overrun thus far, which means that either the 12% or 16% is the probable minimum average deviation above estimated cost.

The high boundary of this range is provided in an article by I. N. Dmitriyev. In it he states, "In 1973 ministries and agencies reviewed the estimated costs for 2,400 construction projects and the increases averaged 29%." [16] This proportion is on the high side because it includes deviations from estimates that were drawn up before the completion of the designs. These preliminary estimates are obviously coarse and inaccurate and deviate from the first revised estimates that the *Sborniki* are supposed to gauge.

Two intermediate estimates are provided in an article by V. P. Krasovskiy. First, he states that in 1,638 leading construction projects the rise in estimated cost during the first two years of the Ninth Five-Year Plan equaled 19 billion rubles or 18%.[17] Presumably this sample includes a large part of Soviet construction because the imputed value of Krasovskiy's sample is 105.6 billion rubles and total planned construction in 1971–72 was 110.4 billion rubles. Second, the Central Statistical Administration in a study of 1971 construction found that for 782 new construction projects and 1,034 construction projects at existing enterprises the rise in estimated costs was 13.5% and 30%, respectively.[18] If the average values projects in each of the above categories were equal, the average

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[13] V. L. Perlamutrov and L. V. Braginskiy, "Cost Accounting Credit and Finance Levers," *Ekonomika i organizatsiya promyshlennogo proizvodstva*, No. 1, 1975, pp. 61–70. Also in JPRS 65219, 14 July 1975.

[14] *Narodnoye khozyaystvo SSSR v 1973 g.*, p. 558.

[15] I. Khizhnyak, "Ways to Decrease Unfinished Production and Construction," *Planovoye khozyaystvo*, No. 7, 1975, pp. 106–109. The article states that at the end of 1973 unfinished construction exceeded normative limits by 16 billion rubles.

[16] I. N. Dmitriyev, "The Most Important Construction Tasks for the Concluding Year of the Five-Year Plan," *Ekonomika stroitel'stva*, No. 3, 1975, pp. 5–11. Also in JPRS 64695, 5 May 1975.

[17] V. P. Krasovskiy, *op. cit.*

[18] *Ibid.*

increase in estimated costs would equal 22.9%.[19] In view of the accumulated evidence, we suggest that the ruble costs should on the average be adjusted upward by at least 20%.

Given the conclusion that Soviet construction costs are understated by an average of 20%, two alternatives can be followed in adjusting the ruble-dollar ratios for individual construction categories such as housing or industrial construction. Ruble-dollar ratios for all types of construction can be adjusted by 20%, or the categories can be adjusted differently with the proviso that the weighted average adjustment be 20%. The simplifying assumption that the average proportion of cost overrun is identical for all types of construction would be fulfilled only by some quirk of fate.

Differences in construction relating to the degree of standardization, technology of construction utilized, the priority of the projects to Soviet policymakers, and the type of project involved are relevant variables affecting the degree of cost overrun. The Soviets have tacitly recognized this in a 1972 decree numbered 560, "On Measures for Ensuring the Lowering of Estimated Construction Costs." In it are established acceptable capital reserves for unforeseen contingencies and expenditures with the reserve expressed as a percentage of estimate cost. The amount of the permitted reserve depends on the type of projects—e.g., industry or housing—and whether the construction is experimental, nonstandard, or standard.[20] Although these reserves are too low to realistically compensate for subsequent cost overruns, they yield a relative indication of the effects of different variables in construction on the size of the probable overrun.

The available evidence supports the idea of using a differential adjustment, but the data are too fragmentary to derive a reliable series of coefficients. On the basis of the 1972 decree and the constraint that the average overrun be 20%, a set of estimated coefficients are derived for purely illustrative purposes in Table 4. Although these coefficients tend to move in the expected direction, they have far too tenuous a foundation to use.

Even though using equal adjustment coefficients represents a departure from reality, we adopt them in this study as the best approach when faced by such skimpy evidence. The resulting adjusted ratios are displayed in Table 5. Computation of the US- and Soviet-weighted ratios appears in Appendix Tables I-3 and I-4. We stress that the 20% upward adjustment made to the ruble-dollar ratios represents purely our subjective assessment to be used or discarded depending on the proclivities of the researcher using these findings.

Comparison of Value of US and Soviet Construction

The unadjusted and adjusted aggregate construction ruble-dollar ratios are compared in the following tabulation:

	Unadjusted	Adjusted
US-weighted ratio	0.621	0.746
Soviet-weighted ratio	0.539	0.647
Geometric mean ratio	0.579	0.695

[19] This is probably a conservative estimate because the cost of new construction projects probably averages more than projects at existing enterprises.

[20] "Lowering of Estimated Construction Costs," *Planovoye khozyaystvo*, No. 10, October 1972, pp. 155–157. Also in JPRS 57413, 2 November 1972.

Table 4

Derivation of Soviet Cost Overrun Coefficients

Percent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Standard		Nonstandard		All Construction			
	Share of Construction of That Type [1]	Relative Overrun Coefficient [2]	Share of Construction of That Type [1]	Relative Overrun Coefficient [2]	Share of Construction of That Type	Relative Overrun Coefficient [3]	Weight in Soviet Construction	Cost Overrun [4]
Industry	25.0	3.00	75.0	6.95	100.0	5.96	36.2	31.4
Transportation and communications except railroad	87.0	3.00	13.0	5.00	100.0	3.26	6.0	17.2
Railroad transport	87.0	3.00	13.0	5.00	100.0	3.26	2.6	17.2
Housing construction	93.5	2.00	6.5	3.50	100.0	2.10	27.0	11.1
Construction of trade and communal enterprises, forestry enterprises, and institutions of science, culture, art, education, and health	85.7	2.00	14.3	7.50	100.0	2.79	28.2	14.7

[1] All categories except industry use the reported figures in *Narodnoye khozyaystvo SSSR v 1970 g.*, p. 497. As mentioned earlier, the claim that 69% of industrial construction is standardized is exaggerated. A better measure of the degree of industrial standardization comes from the statement that consolidated estimating norms can be used for 20%–30% of industrial construction, Malimanov *op. cit.*

[2] These coefficients are adapted from coefficients for the planned capital reserves for unforeseen contingencies. The industry coefficient is a crude weighted average of capital investment in each branch of industry. "Lowering of Estimated Construction Costs," *Planovoye khozyaystvo*, No. 10, 1972, pp. 155–157. Also in JPRS 57413, 2 November 1972.

[3] This is a weighted average of standard and nonstandard construction.

[4] Given the relative magnitude in column 6, these are the overruns that fulfill the requirement that the average overrun using Soviet weights equal 20%.

Table 5

Summary of Adjusted Ruble-Dollar Ratios by Type of Construction

Type of Construction	US Weighted Ratio	USSR Weighted Ratio	Geometric Mean Ratio
Hospitals	0.416	0.331	0.371
Housing	0.744	0.593	0.664
Single-family	N.A.	N.A.	0.775
Multi-family	0.703	0.545	0.619
Office buildings	0.610	0.541	0.574
Schools	0.700	0.601	0.649
Elementary	0.662	0.582	0.621
Intermediate	0.740	0.622	0.678
Industry	N.A.	N.A.	0.721
Light	N.A.	N.A.	0.754
Heavy	N.A.	N.A.	0.691
Roads	N.A.	N.A.	0.948
Airfields	N.A.	N.A.	0.834
Railroads	N.A.	N.A.	1.003
Aggregate construction	0.746	0.649	0.696

These ratios permit an estimate of the magnitude of construction in the United States and USSR in 1970. Soviet construction may be valued in dollars and US construction in rubles.[21]

	Value of US Construction	Value of Soviet Construction
Using unadjusted ruble-dollar ratios		
Billion 1970 dollars	94.2	93.3
Billion 1970 rubles	58.5	50.3
Using adjusted ruble-dollar ratios		
Billion 1970 dollars	94.2	77.7
Billion 1970 rubles	70.3	50.3

The comparisons resulting from these values are as follows (value of USSR construction as a percent of the value of US construction):

	Using Unadjusted Ruble-Dollar Ratios	Using Adjusted Ruble-Dollar Ratios
In 1970 dollar prices	99.0	82.5
In 1970 ruble prices	86.0	71.6
Geometric mean of dollar-ruble comparisons	92.3	76.9

[21] See equations (3) and (4) in Appendix A.

APPENDIX A

THE ALGEBRA OF RUBLE-DOLLAR RATIOS

International comparisons of economic activity always encounter the index number problem unless the mix of economic activity or the relative prices attached to that activity are the same in the countries being compared.* Thus, when the relative volume of Soviet and US construction is examined, the comparison could be made in Soviet or US prices:

$$(1)\quad V_s = \frac{\sum_{i=1}^{n} P_{si}Q_{si}}{\sum_{i=1}^{n} P_{si}Q_{ui}}$$

or,

$$(2)\quad V_u = \frac{\sum_{i=1}^{n} P_{ui}Q_{ui}}{\sum_{i=1}^{n} P_{ui}Q_{si}}$$

Where:

V_s = the ratio of the value of Soviet construction to US construction where both are measured in rubles

V_u = the ratio of the value of US construction to Soviet construction where both are measured in dollars

Q_{si} = the quantity of Soviet construction of type i

P_{si} = the Soviet price of construction of type i

Q_{ui} = the quantity of US construction of type i

P_{ui} = the US price of construction of type i.

To compare construction rigorously in these countries in either the US or Soviet price system would require complete recosting of each project in one of the countries using the other country's prices. Specifically, a comparison using formula (1) demands the revaluation of all US construction in rubles; equation (2) demands the conversion of all Soviet construction into dollars. The effort involved would be far beyond reason, and in any event, the requisite price and quantity data simply are not available.

International price relatives provide a short cut solution to the comparison problem. In this study the relevant price relatives are either ruble-dollar or dollar-ruble ratios. These ratios represent averages of US and Soviet price ratios in which each ratio is given a proportionate weight based on the importance of the given type of construction in the total value of US *or* Soviet construction. Alge-

*The index number problem reflects international differences in tastes, levels of income, natural resources, technology, and state of development.

braically, sample dollar-ruble ratios derived for a category are used with **Soviet** value weights to obtain an average dollar-ruble ratio ($1/R_s$), and sample ruble-dollar ratios derived for a category are used with **US** value weights to obtain an average ruble-dollar ratio (R_u):

$$(3)\quad 1/R_s = \sum_{i=1}^{n} P_{ui}/P_{si} \frac{P_{si}Q_{si}}{\sum_{i=1}^{n} P_{si}Q_{si}} = \frac{\sum_{i=1}^{n} P_{ui}Q_{si}}{\sum_{i=1}^{n} P_{si}Q_{si}}$$

$$(4)\quad R_u = \sum_{i=1}^{n} P_{si}/P_{ui} \frac{P_{ui}Q_{ui}}{\sum_{i=1}^{n} P_{ui}Q_{ui}} = \frac{\sum_{i=1}^{n} P_{si}Q_{ui}}{\sum_{i=1}^{n} P_{ui}Q_{ui}}$$

The results of equations (3) and (4) can then be used to estimate V_s and V_u in equations (1) and (2), above—the comparisons of US and Soviet construction volume in ruble and in dollar prices.

$$(5)\quad V_s = \frac{\sum_{i=1}^{n} P_{si}Q_{si}}{R_u \sum_{i=1}^{n} P_{ui}Q_{ui}}$$

$$(6)\quad V_u = \frac{\sum_{i=1}^{n} P_{ui}Q_{ui}}{1/R_s \sum_{i=1}^{n} P_{si}Q_{si}}$$

Thus, to make comparisons of US and Soviet construction, one needs the value of each country's construction in domestic prices, a US-weighted ruble-dollar ratio, and a Soviet-weighted dollar-ruble ratio. The ratios can be computed from a sample of representative construction projects in each country in the manner described in this study, and the values of construction in domestic prices are reported in national statistics.

APPENDIX B

ADJUSTMENTS FOR LOCATION AND CLIMATE

To find the location representing the average cost in the United States, a sample of one hundred city price indexes from *Building Construction Cost Data 1972* was collected. These indexes provide the relative cost of construction between all these cities in 1971. Since New York City is the most expensive construction location in the contiguous 48 states, all these city indexes were adjusted to a base where New York City equaled 100. By weighting each of these city indexes equally, an arithmetic mean of all the indexes was computed. On the basis of these results, the average construction costs are approximately 83% of those in New York City.

The US data used in this study present costs in one of three ways: (1) average cost for the country, (2) the cost for a major metropolitan area, or (3) the cost at the actual project site. In the first case, there is no need for an adjustment to have average US costs. In the second case, the costs are adjusted to those of New York City and then multiplied by 83% to convert them to the average. In the third case, we located the nearest major metropolitan area for which there is a price index and then used that city as a base to proceed as in the second case.

The determination of the location representing the average cost in the USSR is different. When costing construction with the *Sborniki*, two location identifiers must be assigned to the project under consideration. Each of these identifiers divides the Soviet Union according to a different scheme of regional cost variation. One system, which divides the country into ten territorial zones, allows for variations in material costs resulting from the construction site's remoteness from the source of materials production, and also considers labor costs unique to each area. The other system of locational variation in cost divides the country into four regions to account for cost differences contingent on climatic conditions. (For maps indicating the boundaries of these regional zones, see Figures 1 and 2.)

The precise distribution of construction by territorial zones cannot be determined, because the Soviets do not publish such statistics. The territorial zones sometimes overlap republics, economic regions, oblasts, national okrugs, and krays. Construction data are usually available solely for independent republics and economic regions. Only investment figures (including the cost of machinery installed) are available for lower organizational units.

When the value of construction for one of these lesser organizational units is estimated, the geographical pattern of construction is taken to be similar to that of the economic region or republic. For example, all of the Ural economic region is located in territorial Zone 2 except for Udmurtskaya ASSR, which falls in territorial Zone 1. To distribute construction for this region between Zones 1 and 2, construction in Udmurtskaya ASSR must be isolated from the rest of the

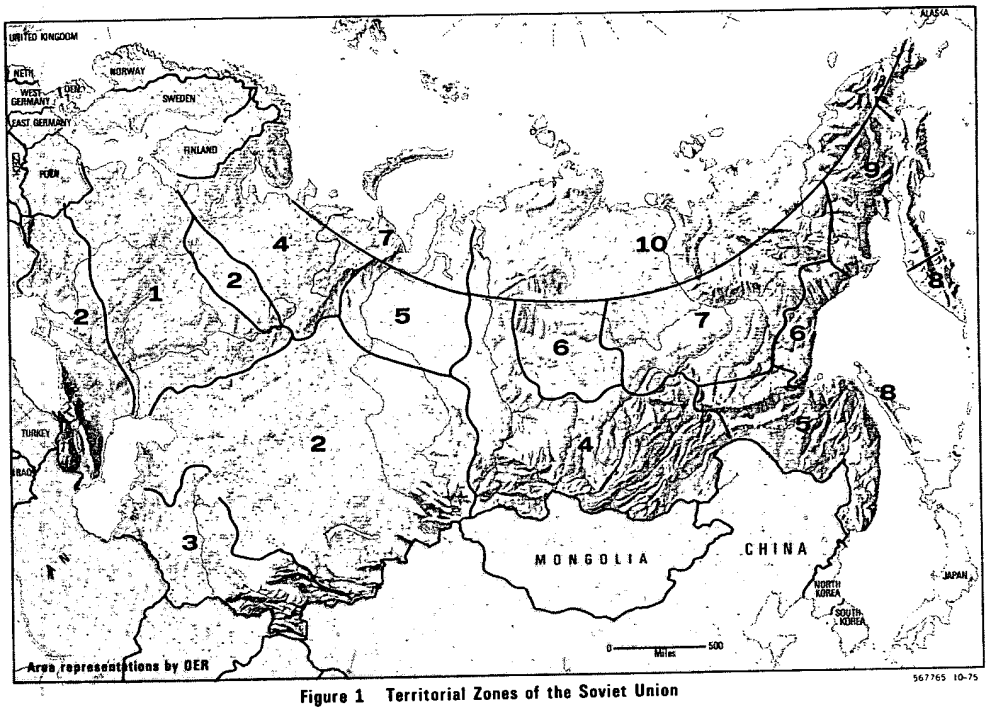

Figure 1 Territorial Zones of the Soviet Union

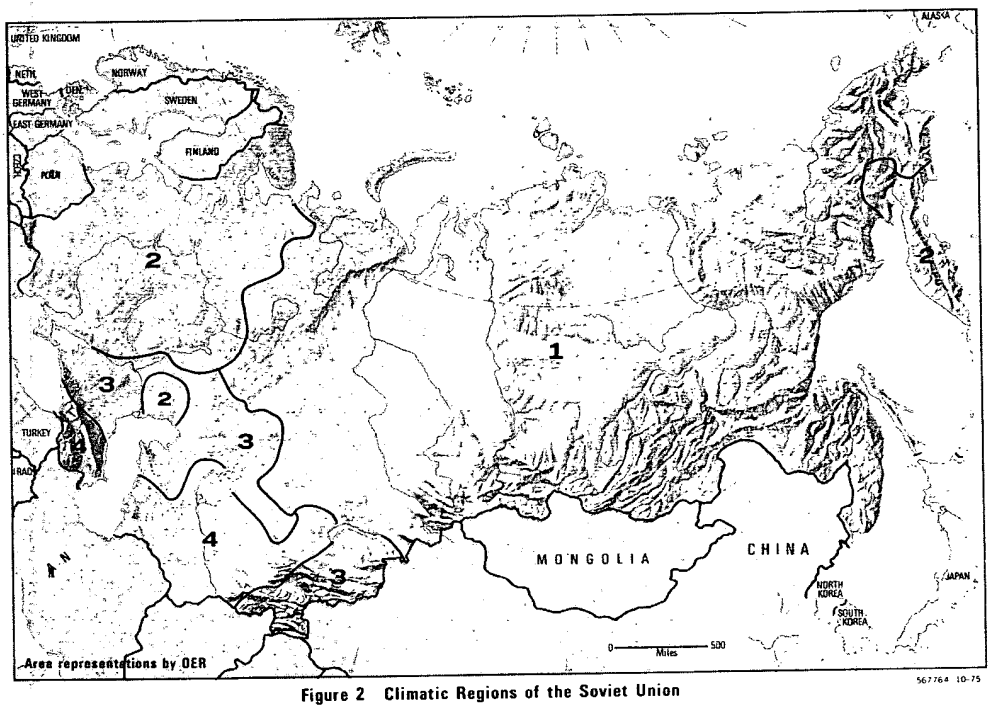

Figure 2 Climatic Regions of the Soviet Union

region. Although a distribution by oblasts and ASSRs is available for capital investment, only the total construction and installation for the Urals region is known, i.e., 2,973 million rubles in 1970. Udmurtskaya ASSR contains 9.0% of the region's capital investment, so its estimated construction is 0.09 x 2,973 million rubles = 267.6 million rubles, and construction for the rest of the region is 2,705.4 million rubles.

Sometimes the allocation of construction to a specific territorial zone is impossible. For example, Yakutskaya ASSR lies in both territorial Zones 7 and 10, and this delineation does not coincide with any administrative boundaries. In such a case, the calculation is performed by alternatively alloting all construction activity to the lowest and then to the highest cost zone in that area. These two extremes provide a range of the possible average-weighted territorial zone. The first calculation is the minimum distribution and the latter the maximum distribution.

The derived distribution is shown in Table B-1. By reviewing the effects of the most extreme assumptions, one can see that the distribution is fairly insensitive to these assumptions, which permits a reasonably accurate estimate of the precise distribution. Because most construction activity is located in the lower zones, the true distribution is undoubtedly closer to the minimum than the maximum. According to this table, 85% of construction activity occurs in territorial Zones 1, 2, and 3. The value of the Soviet median territorial zone

Table B-1

Determination of the Average Territorial Zone in the USSR [1]

Zone	Cost Index [2]	Distribution of Construction by Zone (Percent) [3]	
		Minimum	Maximum
1	100	33.22	33.22
2	104	47.02	45.33
3	112	6.62	6.62
4	120	8.36	4.82
5	127	2.58	1.65
6	172	0	0.93
7	191	0.70	2.61
8	220	0.91	0.59
9	250	0.58	0.90
10	N.A.	0	3.30

[1] Data compiled from *Narodnoye khozyaystvo SSSR 1922–1972, yubileynyy statisticheskiy yezhegodnik; Narodnoye khozyaystvo RSFSR v 1970;* and *Narodnoye khozyaystvo RSFSR v 1971.* All of these statistical handbooks are compiled by the Central Statistical Administration.

[2] This index is derived from a random sample of 25 *Sborniki* tables. Zone 10 is omitted because its costs are presented in two ways: either a fixed cost as in the other zones, or some percentage of the zone south of it. Zone 10 areas have various zones south of them, so there is no uniform zone price. In addition, the volume of construction in Zone 10 is statistically insignificant. Source: Gosstroy USSR, *Sborniki,* Investment Series.

[3] In this table, 7.2% of construction could not be definitely allocated to any one territorial zone. This residual was allocated in terms of the most extreme assumptions to ascertain the limits of the particular oblast or kray; the percentage of construction and installation work in its economic region is the same as its percentage of capital investment. Because of rounding, components may not add to 100%.

provides a measure of the representative Soviet construction location. The median is 2 and, consequently, Zone 2 is used as the average zone for the *Sborniki* costing estimates.

Assumptions analogous to those employed to find the average Soviet territorial zone can be made to obtain patterns of construction by climatic region. The results of these calculations are given in Table B-2. The mean weighted climatic region and the median are approximately equal to Level II, so this regional identifier is used as the average location.

Table B-2

Determination of the Average Climatic Region in the USSR [1]

Region	Cost Index (Region II = 100) [2]	Distribution of Construction by Region (Percent) [3]
I	107.0	30.87
II	100.0	46.09
III	95.8	13.61
IV	94.0	9.40

[1] Data compiled from *Narodnoye khozyaystvo SSSR 1922–1972; Narodnoye khozyaystvo RSFSR v 1970; Narodnoye khozyaystvo Kazakhstana v 1968;* and *Narodnoye gospodarstvo Ukrayins'koyi RSR v 1970* (in Ukrainian). All of these statistical handbooks are compiled by the Central Statistical Administration.

[2] This index is computed from a sample of 43 *Sborniki* climatic correction tables.

[3] Because of rounding, components do not add to 100%. For purposes of this table and because of scarcity of data, it is assumed that construction in Kazahkstan SSR is allocated by oblast proportional to 1968 investment.

APPENDIX C

HOSPITALS

Two approaches are used in deriving the ruble-dollar ratio for hospitals. First, a US-representative ruble-dollar ratio is derived by selecting a sample of US hospitals and costing the sample in rubles and dollars. In the second approach, a Soviet-representative ratio is derived by selecting a sample of Soviet hospitals and costing the sample in rubles and dollars.

The US-Representative Approach

The sample of 28 US general hospital buildings used in the US-representative approach was drawn from the *Dodge Digest* and costed in rubles using the Soviet *Sborniki* and in dollars using the *Dodge Digest* (see Table C-1).

The ruble costing of these 28 hospitals was fairly direct. The appropriate *Sbornik* contains two types of general hospital structures comparable to US construction. The type selected for each comparison with US hospitals depended on the structure with the same construction volume. An adjustment was made to give the Soviet hospital the same number of stories as the US hospital. The hospitals were assumed to have been built in a locale climatically similar to the USSR north of 50 degrees latitude and west of 50 degrees longitude. Also, these buildings are located where regional construction costs apart from climate are average, i.e., most of the western Soviet Union.

For dollar costing, the specifications for the 28 US hospitals were altered to conform as nearly as possible with Soviet practice regarding air-conditioning, built-in equipment, bid date, and regional cost differences. Since most US hospitals are air-conditioned and most Soviet hospitals are not, the cost of air-conditioning had to be deducted from the dollar cost. Although the exact cost of air-conditioning is usually unknown, the maximum is known, so the deduction, which averages 6%, is estimated for each observation. Any built-in equipment included in the *Dodge Digest* was deleted because such equipment is not considered part of Soviet construction costs. The bid prices for US hospital construction, which were scattered over several years in the *Dodge Digest*, were adjusted to June 1970 dollars by the Dodge index of construction costs for the major city nearest each hospital. Finally, 83% of the average construction cost of hospitals in New York City was used to eliminate regional cost differences.

The Soviet-Representative Approach

The sample of 3 Soviet hospital campuses encompassing 23 buildings was selected from *Spravochnik ukrupnennikh pokazateley smetnoy stoimosti i raskhoda resursov zdaniya i sooruzheniya lechebno-profilakticheskikh uchrezhdeniy* (Manual of the Consolidated Indexes of the Estimated Costs and Expenditures of Resources: Buildings and Structures of Medical and Preventive Medicine Institutions), Moscow, 1968, hereafter referred to as *Spravochnik*. The three campuses consisted of: a 1,000-bed hospital with a polyclinic of 1,200 places per day; a 600-bed hospital with a polyclinic of 1,200 places per day; and a 240-bed hospital

Table C-1

Hospital Sample: US-Representative Approach

	(1) Volume of Structure [1] (Cubic Meters)	(2) Unadjusted US Cost per Cubic Meter [2] (US $)	(3) Territorial Adjustment [3] (Index)	(4) Conversion to Mid-1970 Dollars [4] (Index)	(5) Air-Conditioning Adjustment [5] (Index)	(6) Adjusted Total US Cost [6] (Thousand 1970 US $)	(7) Unadjusted Soviet Cost per Cubic Meter [7] (Rubles)	(8) Adjustment for Number of Stories [8] (Index)	(9) Total Soviet Cost [9] (Thousand 1970 Rubles)	(10) Ruble-Dollar Ratio [10]
1.	4,594	66.61	1.186	1.206	0.917	401	24.4	1.00	112	0.279
2.	5,089	106.90	1.038	1.079	1.000	609	24.4	1.00	124	0.204
3.	5,352	71.19	1.012	1.141	0.952	419	24.4	1.00	131	0.313
4.	5,947	66.59	1.012	1.153	0.952	440	24.4	1.00	145	0.330
5.	7,193	73.82	1.092	1.041	0.943	569	24.4	1.00	176	0.309
6.	9,345	84.43	1.038	1.090	0.952	850	24.4	1.00	228	0.268
7.	9,543	66.33	0.922	1.182	1.000	690	24.4	1.00	233	0.338
8.	9,700	73.30	1.051	1.046	0.952	744	24.4	1.00	237	0.319
9.	11,901	61.42	1.153	1.075	0.943	854	26.1	0.98	304	0.356
10.	12,110	90.01	1.064	1.077	0.943	1,178	26.1	1.00	316	0.268
11.	12,488	80.00	1.064	1.143	0.952	1,157	26.1	1.00	326	0.282
12.	12,549	69.41	1.078	1.202	0.926	1,045	26.1	1.00	328	0.314
13.	13,252	78.63	1.186	1.206	0.917	1,367	26.1	1.00	346	0.253
14.	15,073	76.23	1.092	1.041	0.917	1,198	26.1	1.00	393	0.328
15.	16,505	87.55	1.145	0.933	0.930	1,436	26.1	1.00	431	0.300
16.	17,064	76.71	1.137	1.208	0.893	1,605	26.1	0.98	436	0.272
17.	17,399	83.74	1.137	1.040	0.917	1,580	26.1	0.98	445	0.282
18.	20,394	64.92	1.137	1.093	0.926	1,524	35.1	0.98	702	0.461
19.	20,918	79.79	0.988	1.000	0.952	1,570	35.1	1.00	734	0.468
20.	24,239	78.30	1.137	1.093	0.917	2,163	35.1	0.98	834	0.386
21.	24,385	95.46	0.965	1.114	0.952	2,382	35.1	0.98	839	0.352
22.	31,600	83.67	0.954	1.108	0.952	2,661	35.1	1.00	1,109	0.416
23.	35,396	87.38	0.943	1.183	0.952	3,285	35.1	0.98	1,218	0.371
24.	35,793	115.67	0.976	1.053	0.935	3,978	35.1	1.00	1,256	0.316
25.	64,099	64.51	1.092	1.169	0.917	4,840	28.4	0.98	1,784	0.368
26.	72,475	69.17	1.000	1.167	0.943	5,517	28.4	0.95	1,955	0.354
27.	75,351	102.24	0.976	1.154	0.962	8,347	28.4	1.03	2,204	0.264
28.	143,392	65.36	1.051	1.146	0.943	10,645	30.9	1.03	4,564	0.429
Unweighted ruble-dollar ratio										0.329
Value-weighted ruble-dollar ratio						63,054			21,910	0.347

[1] *Dodge Digest*, March 1971, pp. E101–106. Construction volumes have been converted from cubic feet to cubic meters.

[2] *Ibid.* Total construction costs excluding the cost of built-in equipment are divided by the construction volume.

[3] *Ibid.* pp. O–V. The index for each city in 1970 based on New York = 100 is shifted to a base of 83 to account for regional differences.

[4] *Ibid.* The coefficient to adjust bid date dollars to 1970 is obtained by dividing the city index for 1970 by the city index for the bid date.

[5] Reciprocals of individually determined approximations of air-conditioning costs as a percent of total costs.

[6] Column (1) x column (2) x column (3) x column (4) x column (5).

[7] *Sborniki, Budget Series*, no. 5, pp. 7–8.

[8] *Ibid.*, p. 4.

[9] Column (1) x column (7) x column (8).

[10] Column (9) ÷ column (6).

with a polyclinic of 500 places per day. This sample of buildings contains main buildings, kitchen and dining facilities, pathology buildings, and a transformer substation (see Table C-2).

Table C-2

Hospital Sample: Soviet-Representative Approach

	(1) Volume of Structure [1] (Cubic Meters)	(2) US Cost per Cubic Meter [2] (US $)	(3) Air-Conditioning Adjustment [3] (Index)	(4) Adjusted Total US Cost [4] (Thousand 1970 US $)	(5) Unadjusted Soviet Cost per Cubic Meter [5] (Rubles)	(6) Adjustment for Number of Stories [6] (Index)	(7) Total Soviet Cost [7] (Thousand 1970 Rubles)	(8) Ruble-Dollar Ratio [8]
1.....	108,307	111.95	0.940	11,397	30.9	0.97	3,246	0.285
2.....	16,409	109.15	0.940	1,684	24.2	0.98	389	0.231
3.....	21,099	109.82	0.940	2,178	23.8	0.98	492	0.226
4.....	2,547	99.33	0.940	238	39.4	1.00	100	0.420
5.....	3,507	99.23	0.940	327	32.1	1.00	113	0.346
6.....	8,194	99.22	0.940	764	27.9	1.00	229	0.300
7.....	2,400	99.17	0.940	224	39.5	1.00	95	0.424
8.....	262	99.24	0.940	24	34.6	1.00	9	0.375
9.....	78,792	111.95	0.940	8,292	28.4	1.03	2,305	0.278
10.....	12,125	102.02	0.940	1,163	24.2	1.00	293	0.252
11.....	21,099	109.82	0.940	2,178	23.8	0.98	492	0.226
12.....	2,547	99.33	0.940	238	39.4	1.00	100	0.420
13.....	2,645	99.06	0.940	246	32.1	1.00	85	0.346
14.....	6,640	99.25	0.940	619	27.9	1.00	185	0.299
15.....	2,031	99.46	0.940	190	39.5	1.00	80	0.421
16.....	210	100.00	0.940	20	34.6	1.00	7	0.350
17.....	19,680	109.81	0.940	2,031	26.1	0.98	503	0.248
18.....	4,542	99.30	0.940	424	24.4	1.00	111	0.262
19.....	6,500	99.23	0.940	606	27.2	1.00	177	0.292
20.....	1,137	99.38	0.940	106	32.1	1.00	36	0.340
21.....	3,115	99.20	0.940	290	35.1	1.00	109	0.376
22.....	825	99.39	0.940	77	33.9	1.00	28	0.364
23.....	235	97.87	0.940	22	34.6	1.00	8	0.364
Unweighted ruble-dollar ratio for buildings								0.324
Value-weighted ruble-dollar ratio				33,338			9,192	0.276

[1] *Spravochnik ukrupnennikh pokazateley smetnoy stoimosti i raskhoda resursov, zdaniya i sooruzheniya lechebno-profilakticheskikh uchrezhdeniy*, pp. 11–46, 65–74. The structures identified by number in the table are:

1. Main hospital building with 810 beds
2. Infectious ward with 120 beds
3. Outpatient (polyclinic) facilities for 1,200 patients per day
4. Radiology building with hospital of six beds
5. Food service building
6. Support services building
7. Pathology building
8. Transformer substation
9. Main hospital building with 510 beds
10. Infectious ward with 84 beds
11. Outpatient facilities for 1,200 patients per day
12. Radiology building with hospital of six beds
13. Food services building
14. Support services building
15. Pathology building
16. Transformer substation
17. Main hospital building with 200 beds
18. Infectious ward with 40 beds
19. Outpatient facilities for 500 patients per day
20. Food service building
21. Support services building
22. Pathology building
23. Transformer substation

[2] *Dodge Guide*, p. 4–3. US costs given on a square foot basis are converted to cubic feet and subsequently to cubic meters with the assumption that the height of a story averages 11.6 feet.

[3] 6% is assumed throughout.

[4] Column (1) x column (2) x column (3).

[5] *Sborniki, Budget Series*, no. 5, pp. 7–24, and *Sborniki, Investment Series*, no. 3, p. 175.

[6] *Sborniki, Budget Series*, no. 5, *op. cit.*, p. 4.

[7] Column (1) x column (5) x column (6).

[8] Column (7) ÷ column (4).

The ruble costs for these three campuses were taken from the *Sborniki* and applied to the physical facilities assumed to be built in the same location as described in the US-representative approach.

The Soviet hospitals are costed in dollars using the *Dodge Guide*, which gives US dollar costs as of mid-1970, and are averaged to allow for geographic differentials. Average quality US hospitals are used for comparison with the Soviet hospitals, but the US costs are reduced by 6% to eliminate the cost of air-conditioning.

Results

The estimates are summarized in Table C-3. The US-representative sample has a larger average building size than the Soviet-representative sample. The unweighted ruble-dollar ratios for US and Soviet methodologies are 0.33 and

Table C-3

Hospitals

		Range	
	Average	**Minimum**	**Maximum**
I. US-Representative Methodology (Sample size: 28 buildings)			
Volume (cubic meters)	26,184	4,594	143,392
Soviet cost (thousand rubles)	782	112	4,564
US cost (thousand US $)	2,252	401	10,645
Soviet weighted cost (rubles per cubic meter)	29.9	24.4	33.1
US weighted cost (dollars per cubic meter)	86.0	71.76	119.67
Unweighted ruble-dollar ratios	0.329	0.204	0.468
Value-weighted ruble-dollar ratio	0.347		
II. Soviet-Representative Methodology (Sample size: 3 campuses, 23 buildings)			
Volume (cubic meters)			
Campus	108,283	36,034	162,725
Building	14,124	210	108,307
Soviet cost (thousand rubles)			
Campus	3,068	973	4,684
Building	400	7	3,246
US cost (thousand US $)			
Campus	11,822	3,784	13,772
Building	1,449	20	11,397
Soviet weighted cost (building) (rubles per cubic meter)	28.3	23.3	39.5
US weighted cost (building) (dollars per cubic meter)	108.4	91.60	105.24
Unweighted ruble-dollar ratios			
Campus	0.276	0.273	0.279
Building	0.324	0.226	0.424
Value-weighted ruble-dollar ratio (building)	0.276		

0.32, respectively, and the coefficient of variation—i.e., the ratio of the standard deviation to the mean—is about 20% in each case. A 95% confidence interval around the mean gives an interval estimate of 0.30 to 0.35 in both cases. A test of the dispersion of the project ruble-dollar ratios about the mean suggests a strong central tendency.*

*This test was conducted by separately dividing the sample of ruble-dollar ratios obtained by each method into a frequency distribution of six classes which are: from two to three, one to two, and zero to one standard deviations both above and below the average ruble-dollar ratio. The expected frequency of occurrence in each class of the sample of ratios, if the sample were normally distributed, was then computed. A chi-square test of the relationship between the actual sample frequency and the frequency predicted by the normal distribution resulted in chi-square values of 6.38 and 2.78 for the US-representative and Soviet-representative samples, respectively. These values are not sufficiently large to refute the assertion that there is a 95% probability that the sample of ratios in each case is normally distributed and that, therefore, there is a strong central tendency.

On the other hand, the value-weighted ruble-dollar ratio is lower in the Soviet-representative sample. This accords with expectations because Soviet builders should do relatively better at the construction of their own types of buildings than they should at duplicating American projects. The value-weighted ruble-dollar ratios are used for computation of the aggregate hospital ratio by taking the geometric mean of each approach's ratio; this results in a hospital ratio equal to 0.309.

The relationship between the unweighted ratio and the value-weighted ratio should provide a clue of the effect of scale, if any, on the ruble-dollar ratio as was discussed earlier. The results in this case are ambiguous because the US-representative sample suggests the ruble-dollar ratio increases with project size, but the Soviet-representative sample indicates the opposite. With such results, the effect of scale must be inconclusive.

APPENDIX D

HOUSING

The ruble-dollar ratio for housing construction is computed by developing a sample of ratios for specific types of housing. These ratios are then aggregated into two weighted averages: one average is based on US construction weights and the other is based on Soviet construction weights. The geometric mean of the two ratios provides the aggregate housing construction ruble-dollar ratio.

The Approach

A sample of 69 different types of housing construction is used to determine the aggregate ratio. This sample is selected so that unique features of buildings pertinent to construction in either country are represented. For example, there are ruble-dollar ratios for both four- and five-story walk-up apartments, which are so common in the USSR and rare in the United States, and the four- and five-story buildings with elevators, which are typical of US practices and atypical in the USSR. Other features that distinguish the categories in the sample include number of family units (single-family versus multi-family), number of stories, and the inclusion or exclusion of basements. The buildings are then costed in rubles from the *Sborniki* and in dollars from the *Dodge Guide* as shown in Table D-1. Again, the buildings are costed for average locations in each country to eliminate regional cost differentials. The actual costing of the sample varies according to the unique features of the buildings described below.

The sample of single-family dwellings contains seven buildings based on Soviet designs contained in *Al'bom proyektov dlya sel'skogo stroitel'stva: zhilyye zdaniya dlya individual'nogo stroitel'stva* (Album of Plans for Rural Construction: Housing for Individual Construction). The floorspace in these structures is computed from the floor plans and cross-sections in the book. These areas are adjusted by subtracting one-half of the area of any verandas included to be consistent with the American Institute of Architect's standards for computing floor area. Although several of the buildings' construction volumes are published, close examination reveals that many of the volumes have errors and differ from Soviet standards for measuring volume, so independent volume estimates are made. Since Soviet single-family housing is usually of low quality, these Soviet buildings are compared with US construction of single-family, masonry wall, low-quality structures.

The best quality one-, two-, and three-story Soviet apartment buildings are compared with average US quality, masonry wall garden apartments with the same number of floors. For each of these building heights, construction costs are a function of both unit area and building volume. Since the *Dodge Guide* costs are presented on the basis of average unit size, both the minimum and maximum

[pp. 32 blank]

Table D-1

The Housing Sample

(1) Type of Structure	(2) Floor Space[1] (Square Meters)	(3) US Cost per Square Meter[2] (US $)	(4) Total US Cost[3] (Thousand 1970 US $)	(5) Structure by Volume[4] (Cubic Meters)	(6) Soviet Cost per Cubic Meter[5] (Rubles)	(7) Total Soviet Cost[6] (Thousand 1970 Rubles)	(8) Ruble-Dollar Ratio[7]
Single family housing	131.2	151.75	19.9	438.0	24.5	10.7	0.538
	68.7	171.08	11.8	252.0	26.4	6.7	0.568
	97.5	165.15	16.1	409.0	25.1	10.3	0.640
	97.5	165.15	16.1	372.0	25.0	9.3	0.578
	191.4	108.40	20.7	564.0	23.0	13.0	0.628
	189.6	99.22	18.8	538.0	27.7	14.9	0.793
	140.5	121.65	17.1	552.0	24.1	13.3	0.778
Average	130.9	140.33	17.2	446.0	25.1	11.2	0.646
One-story apartment							
Small building	104.5	114.89	12.01	312.1	27.2	8.49	0.708
	139.4	104.51	14.57	416.2	26.6	11.07	0.760
Large building	104.5	114.89	12.00	312.1	22.7	7.08	0.590
	139.4	104.51	14.57	416.2	22.2	9.24	0.634
Average	122.0	109.70	13.29	364.2	24.7	8.97	0.673
Two-story apartment							
Small building	104.5	107.31	11.21	312.1	23.3	7.27	0.649
	139.4	97.96	13.66	416.2	22.8	9.49	0.695
Large building	104.5	107.31	11.21	312.1	20.6	6.43	0.574
	139.4	97.96	13.66	416.2	20.1	8.37	0.613
Average	122.0	102.64	12.44	364.2	21.7	7.89	0.633
Three-story apartment							
Small building	104.5	103.52	10.82	312.1	24.2	7.55	0.698
	139.4	94.35	13.15	416.2	23.7	9.86	0.750
Large building	104.5	103.52	10.82	312.1	23.0	7.18	0.664
	139.4	94.35	13.15	416.2	22.5	9.36	0.712
Average	122.0	98.94	11.98	364.2	23.4	8.49	0.706
Four-story apartment							
With elevators	3,716	216.27	804	11,359	27.9	317	0.394
	13,935	169.65	2,364	42,527	26.5	1,127	0.477
Without elevators	3,716	207.20	770	11,359	25.1	285	0.370
	13,935	162.53	2,265	42,527	23.8	1,012	0.447
Average	8,826	188.91	1,551	26,943	25.8	685	0.422
Five-story apartment							
With elevators	3,716	216.27	804	11,359	27.5	312	0.388
	13,935	169.65	2,364	42,527	26.1	1,110	0.470
Without elevators	3,716	207.20	770	11,359	24.0	273	0.355
	13,935	162.53	2,265	42,527	22.8	970	0.428
Average	8,826	188.91	1,551	26,943	25.1	666	0.410
Six-story apartment	3,716	190.29	707	11,359	27.7	315	0.446
	13,935	157.54	2,195	42,572	25.6	1,090	0.497
Average	8,826	173.92	1,451	26,966	26.6	702	0.472
Seven-story apartment							
With basement	3,716	195.37	726	11,338	29.9	339	0.467
	23,225	156.33	3,631	70,878	26.4	1,871	0.515
Without basement	3,716	216.88	806	11,338	27.3	310	0.385
	23,225	169.65	3,940	70,878	25.5	1,807	0.459
Average	13,470	184.56	2,276	41,108	27.3	1,082	0.457
Eight-story apartment							
With basement	3,716	197.79	735	11,338	29.1	330	0.449
	23,225	158.16	3,673	70,878	27.3	1,935	0.527
Without basement	3,716	216.88	806	11,338	26.9	305	0.378
	23,225	169.65	3,940	70,878	25.1	1,779	0.452
Average	13,470	185.62	2,288	41,108	27.1	1,087	0.452
Nine-story apartment							
With basement	3,716	199.71	742	11,338	31.2	354	0.477
	23,225	159.34	3,701	70,878	32.3	2,289	0.618
Without basement	3,716	216.88	806	11,338	26.7	303	0.376
	23,225	169.65	3,940	70,878	24.2	1,715	0.435
Average	13,470	186.40	2,297	41,108	28.6	1,165	0.477

Table D-1

The Housing Sample (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Type of Structure	Floor Space [1] (Square Meters)	US Cost per Square Meter [2] (US $)	Total US Cost [3] (Thousand 1970 US $)	Structure by Volume [4] (Cubic Meters)	Soviet Cost per Cubic Meter [5] (Rubles)	Total Soviet Cost [6] (Thousand 1970 Rubles)	Ruble-Dollar Ratio [7]
Ten-story apartment							
With basement	3,716	201.30	748	11,338	29.5	334	0.447
	23,225	160.24	3,722	70,878	29.5	2,091	0.562
Without basement	3,716	216.88	806	11,338	36.3	412	0.511
	23,225	169.65	3,940	70,878	36.3	2,573	0.653
Average	13,470	187.02	2,304	41,108	32.9	1,352	0.543
Eleven-story apartment							
With basement	3,716	202.60	753	11,338	31.3	355	0.471
	23,225	161.04	3,740	70,878	31.3	2,218	0.593
Without basement	3,716	216.88	806	11,338	34.2	388	0.481
	23,225	169.65	3,940	70,878	34.2	2,424	0.615
Average	13,470	187.54	2,310	41,108	32.8	1,346	0.540
Twelve-story apartment							
With basement	3,716	203.72	757	11,338	33.1	375	0.495
	23,225	161.79	3,758	70,878	33.1	2,346	0.624
Without basement	3,716	216.88	806	11,338	31.6	358	0.444
	23,225	169.65	3,940	70,878	31.6	2,240	0.569
Average	13,470	188.01	2,315	41,108	32.4	1,330	0.533
Thirteen-story apartment							
With basement	3,716	204.66	761	11,338	32.0	363	0.477
	23,225	162.32	3,770	70,878	32.0	2,268	0.602
Without basement	3,716	216.88	806	11,338	32.0	363	0.450
	23,225	169.65	3,940	70,878	32.0	2,268	0.576
Average	13,470	188.38	2,319	41,108	32.0	1,316	0.526
Fourteen-story apartment							
With basement	3,716	205.48	764	11,338	30.9	350	0.458
	23,225	162.85	3,782	70,878	30.9	2,190	0.579
Without basement	3,716	216.88	806	11,338	30.9	350	0.434
	23,225	169.65	3,940	70,878	30.9	2,190	0.556
Average	13,470	188.72	2,323	41,108	30.9	1,270	0.507
Fifteen-story apartment							
With basement	3,716	206.20	766	11,338	33.8	383	0.500
	23,225	163.30	3,793	70,878	33.8	2,396	0.632
Without basement	3,716	216.88	806	11,338	33.8	383	0.475
	23,225	169.65	3,940	70,878	33.8	2,396	0.608
Average	13,470	189.01	2,326	41,108	33.8	1,390	0.554
Sixteen-story apartment							
With basement	3,716	205.86	765	11,338	32.8	372	0.486
	23,225	163.69	3,802	70,878	32.8	2,325	0.612
Without basement	3,716	216.88	806	11,338	32.8	372	0.462
	23,225	169.65	3,940	70,878	32.8	2,325	0.590
Average	13,470	189.02	2,328	41,100	32.8	1,348	0.538

[1] The floorspace areas for one- to three-story apartments are based on the average size of one unit, but all other areas are based on total floorspace of the building. The areas for the single family housing are adjusted from *Al'bom proyektov dlya sel'skogo stroitel'stva: zhilyye zdaniya dlya individual'nogo stroitel'stva* by halving the given area of any verandas to conform with American Institute of Architects' guidelines. The floorspace areas of multifamily housing are derived from the *Dodge Guide*, pp. 1–52, 1–56, 1–60.

[2] *Dodge Guide*, pp. 1–29, 1–52, 1–56, 1–60. For buildings above three stories, the costs of air-conditioning are excluded by multiplying the given costs by a factor of 0.954. To determine the US cost of four- and five-story walk-up apartments, the construction costs are reduced an additional 4% to remove the cost of elevators. This coefficient is derived from *Building Construction Cost Data 1972*, by R. S. Means Company, Inc.

[3] Column (2) x column (3).

[4] Construction volumes for one- to three-story multifamily housing are the sizes of average units. The volumes for the single-family housing are computed from the floor plans in *Al'bom proyektov, op. cit.*, because the stated volumes in several cases seem erroneous and not in conformity with Soviet methods for computing construction volume. The volumes for multifamily units are from *Dodge Guide*, pp. 1–52, 1–56, 1–60, 1–74.

[5] *Sborniki, Budget Series*, No. 4, pp. 3–81. *Sborniki, Investment Series*, No. 28, pp. 3–38.

[6] Column (5) x column (6).

[7] Column (7) ÷ column (4).

unit sizes are costed. These alternative unit sizes are in turn costed for both the smallest and largest buildings with the same number of stories that are listed in the *Sborniki*. The four ratios that are computed for apartment buildings with a given number of stories can be arranged in the following matrix:

	Smallest Soviet Building in the *Sborniki*	Largest Soviet Building in the *Sborniki*
Smallest average apartment in the *Dodge Guide*	r_{11}	r_{12}
Largest average apartment in the *Dodge Guide*	r_{21}	r_{22}

The major difficulty in estimating ruble-dollar ratios for apartment buildings lies in matching Soviet costs per cubic meter of building with US costs per square meter of apartment space (excluding non-apartment areas such as common halls). The size of an apartment is equivalent to what the Soviets call useful space. Soviet urban apartments are constructed so that living space averages approximately two-thirds of useful space. A descriptive statistic, K_2, appears frequently in Soviet housing literature and is defined as the ratio of a structure's construction volume to living space. In a survey of published housing plans, K_2 averages 5.6 in the Soviet Union. The above relationships provide a direct link between the US and Soviet ways of expressing cost.*

High-quality Soviet four-, five-, and six-story apartments are compared with average US quality, masonry wall, medium-rise apartments. In these categories, total costs are based primarily on total building size instead of the average size of apartment units. Accordingly, both the smallest and largest buildings listed in the *Dodge Guide* are costed for a given number of stories. The four- and five-story buildings are priced in both rubles and dollars, with and without elevators, in order to represent differences in construction practices in the two countries. Six-story buildings, however, possess elevators in both countries. Since all the medium-rise apartments in the *Dodge Guide* contain elevators, the cost of elevators is excluded by reducing total construction costs by 4%—the average proportion of construction costs allocated to elevators in US apartment construction. Moreover, the US buildings are air-conditioned, so this cost is also

*Useful space is the total floor area of a building minus the space of external halls, stairways, and external elevator shafts common to more than one unit and the space occupied by walls. Living space is the area devoted to living rooms and bedrooms only.

Let: V = volume of a building
L = living space
U = useful space
$K_2 = V/L$
Since: $K_2 = 5.6$, and
$L = (2/3) \cdot U$
Therefore: $V = 5.6L = 5.6(2/3)U = 3.73U$

See Willard S. Smith, "Housing in the Soviet Union—Big Plans, Little Action," in *Soviet Economic Prospects for the Seventies*, p. 406.

removed. For 14 apartment buildings in the *Dodge Digest*, the cost of air-conditioning can be isolated from total cost. The cost of air-conditioning in this small sample averages 4.6% of total cost, with a range from 1.7% to 9.4%. This average is used as the coefficient to reduce the *Dodge Guide* costs.

The highest quality Soviet 7- to 16-story apartments are compared with average US-quality, concrete-frame, high-rise buildings. These buildings are costed in both basement and non-basement versions for the smallest and largest buildings in the *Dodge Guide*. The cost of air-conditioning is eliminated with the same coefficient used for medium-rise apartments.

The ruble-dollar ratio for housing is a specially constructed average of the individual building ratios. The ruble-dollar ratio for each particular type of housing is the computed arithmetic mean of all the ratios of that type of construction (e.g., single-family houses and five-story apartments). Unfortunately, the Soviet data lack sufficient detail to permit the computation of value weights for each category of housing construction. For example, although it is possible to estimate the proportion of Soviet housing construction represented by both three- and four-story apartments, the percentage that is three-story as opposed to four-story is not estimable. Whenever this problem is encountered, the categories are combined by geometric means up to the level of aggregation for which a value weight can be estimated. In the above example, the geometric mean of the three- and four-story ratios represents the three- and four-story group. These geometric means are further combined by value weights into US- and Soviet-weighted ruble-dollar ratios for housing construction.

Value weights are derived for US housing construction in 1970. The relative weights of single-family and multi-family dwellings correspond to the value of new construction put in place during 1970 for one-unit and two or more unit structures. These relative values are directly available only for private construction; however, only the gross value total is available for public housing. Of course, the preponderance of public housing is multi-family housing, but a small single-family portion exists. This relationship is estimated by using a breakdown of the number of construction starts of new units for public housing. This represents a departure from strict value weights, however, because it assumes that the units costs for public housing are totally unrelated to the number of units per structure.

The weights within the multi-family category are based on a sample of 74 apartment buildings from the *Dodge Digest*. These buildings are classified by number of stories, and the total value of construction in each classification is computed. On the basis of this sample, the percentage distribution of the total provides the weights within the multi-family sector. In order to improve this sample by making it larger and more representative, the sample is not confined solely to buildings erected in 1970. Although some were built either a few years before or after 1970, the difference is negligible because distribution of number of stories changes slowly over time. Another problem of bias in the weights exists, however, because very tall buildings, for which we lack a meaningful ruble-dollar ratio, are excluded. Correction of this omission would probably raise the ruble-dollar ratio for housing.

Estimation of the Soviet weights proceeds from the tenuous assumption that the sample's average ruble cost for each category of housing varies in the

same proportion as the actual average for all housing construction of that type.* The ratio of single-family to multi-family housing, as measured by the quantity of useful space constructed, is estimated by assuming that single-family housing and private housing are identical and then by applying published 1970 data arranged on this basis. Value weights are derived by multiplying these quantity proportions by the average cost per cubic meter and adjusting the results to add to unity. The weights within the multi-family housing category are obtained by examining the distribution of state housing construction, by number of stories as measured by useful space in 1970. These weights are shifted to a value basis by a procedure analogous to that described above.

Results

The derivation of the housing ruble-dollar ratio is given in Table D-2. The results are summarized in the following tabulation:

	US-weighted ratio	USSR-weighted ratio	Geometric Average
Single-family housing.....	0.646	0.646	0.646
Multi-family housing.....	0.586	0.454	0.516
All housing.....	0.620	0.494	0.553

The ratios by type of structure and number of stories suggest that Soviet costs are highest relative to US costs in the construction of single-family housing, low-rise apartments (1–3 stories), and high-rise buildings. The primary Soviet advantage lies in the construction of medium-rise buildings, especially the five-story apartments prevalent in the USSR. As expected in international comparisons of this kind, however, the Soviet-weighted ratios are less than the US-weighted ratios.

The ratios in Table D-1 provide further insight concerning factors influencing the ratio. The ruble-dollar ratio is higher for buildings with elevators than for those without them. Elevators in the USSR are expensive—many are imported—and frequently are a large component of total cost. Furthermore, the ruble-dollar ratio is directly related to construction volume for low-rise apartments, but the ratio is inversely related to size for buildings above three stories. This suggests that the USSR has relatively greater scale economies in construction than the United States, but the inclusion of elevators and other costs incurred by making buildings taller negates this advantage. Finally, structures with a basement, except for the 10- and 11-story buildings, have higher ruble-dollar ratios than those without one. Perhaps this is the consequence of greater US efficiency in performing excavation work.

*This assumption may be mathematically expressed as follows:

$$\frac{\overline{X_1}}{\mu_1} = \frac{\overline{X_2}}{\mu_2} = \cdots \frac{\overline{X_n}}{\mu_n} = k$$

where,

$\overline{X_i}$ = average ruble cost per cubic meter in the sample of housing of type i
μ_i = average ruble cost per cubic meter in all housing of type i
k = a scalar constant

Table D-2

The Housing Results

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Type of Structure	**Ruble-Dollar Ratio**	**Group Ruble-Dollar Ratio [1]**	**US Group Weights [2]**	**Composition of US-Weighted Ruble-Dollar Ratio [3]**	**Group Dollar-Ruble Ratio [4]**	**Soviet Group Weights [5]**	**Composition of Soviet-Weighted Dollar-Ruble Ratio [6]**
Single-family housing	0.646	0.646	0.584	0.377	1.548	0.275	0.426
Multi-family housing							
One-story	0.673	0.653	0.202	0.132	1.531	0.091	0.139
Two-stories	0.633						
Three-stories	0.706	0.546	0.044	0.024	1.832	0.061	0.112
Four-stories	0.422						
Five-stories	0.410	0.410	0.006	0.002	2.439	0.421	1.027
Six-stories	0.472	0.464	0.034	0.016	2.155	0.127	0.274
Seven-stories	0.457						
Eight-stories	0.452						
Nine-stories	0.477						
Ten-stories	0.543	0.534	0.130	0.069	1.873	0.025	0.047
Eleven-stories	0.540						
Twelve-stories	0.533						
Thirteen-stories	0.526						
Fourteen-stories	0.507						
Fifteen-stories	0.554						
Sixteen-stories	0.538						
Average weighted ratios for all housing.				0.620			2.025

Geometric mean of US- and Soviet-weighted ruble-dollar ratios = $(0.620 \times \frac{1}{2.025})^{\frac{1}{2}} = 0.553$.

[1] Geometric mean of ruble-dollar ratios for each story group.

[2] *Dodge Digest*, September 1972, pp. K101–K109, and *Construction Review*, September 1974, p. 25.

[3] Column (3) x column (4).

[4] Reciprocal of column (3).

[5] The weight for single-family structures versus multi-family structures is obtained by the assumption that all private construction is single-family and no state or co-op housing is. All the Soviet weights are derived from data in Willard S. Smith, "Housing in the Soviet Union—Big Plans, Little Action," *Soviet Economic Prospects for the Seventies*, June 1973, pp. 412, 423.

[6] Column (6) x column (7). The Soviet-weighted ruble-dollar ratio equals 0.494.

APPENDIX E

OFFICE BUILDINGS

Two approaches are used in deriving a ruble-dollar ratio for the construction of office buildings. The first approach uses a quasi-random sample from the *Dodge Digest* and computes the ratio with a methodology analogous to the US-representative approach for hospitals (see Appendix C). Alternatively, a stratified sample of office buildings is formed by using the *Dodge Guide* for US costs and the *Sborniki* for Soviet costs.

The Dodge Digest Approach

The best Soviet office buildings are compared with US construction to minimize problems of comparability. Thus, the most durable structure in any office building category in the *Sborniki* is always used. These categories are classified by the number of stories in the building. For most buildings, the cost estimator has an option between a simple (*prostaya*) and an enhanced (*povishennaya*) interior finish, the latter being 7%–11% more expensive than the simple one. The enhanced finish is more comparable to the quality of US construction and is used in this study. Adjustments are made to the cost of Soviet buildings, when appropriate, for including items such as hot-water supply, elevators, cloth-backed linoleum, and precast reinforced concrete roofing sheets with interior waterproofing. Data for the US and Soviet cost estimates are given in Table E-1.

The US costs of the 32 office buildings are adjusted to conform to Soviet practice. The cost of built-in equipment is deducted from the US cost. The cost of air-conditioning in each element of the sample is unknown, so building costs are reduced by 6.8%—the average estimated from an admittedly limited sample of 13 office buildings where the cost of air-conditioning was ascertained. As with hospitals, the bid prices are adjusted to June 1970 dollars by the Dodge index of construction costs for the nearest major city and converted to 83% of the construction costs of New York City to eliminate regional disparities.

The Dodge Guide Approach

This approach uses two weighted averages to compute the office building ratio. The methodology for estimating the weighted averages is analogous to the procedure used in Appendix B for housing construction. A ruble-dollar ratio for a building with a given number of stories is derived by using the arithmetic mean of the smallest and largest office buildings in the *Dodge Guide*. The ratios for each building height are then grouped to conform with estimable Soviet weights, with the geometric mean of the elements in each group serving as the applicable ratio for that group. These groups are further combined into Soviet- and US-weighted ruble-dollar ratios, with the geometric mean providing the ultimate result.

Table E-1

Office Building Sample: Dodge Digest Approach

	(1) Volume of Structure [1] (Cubic Meters)	(2) Unadjusted US Cost per Cubic Meter [2] (US $)	(3) Territorial Adjustment [3] (Index)	(4) Conversion to mid-1970 US $ [4] (Index)	(5) Adjusted Total US Cost [5] (Thousand 1970 US $)	(6) Unadjusted Soviet Cost per Cubic Meter [6] (Rubles)	(7) Amenities Correction [7] (Index)	(8) Total Soviet Cost [8] (Thousand 1970 Rubles)	(9) Ruble-Dollar Ratio [9]
1	1,014	62.50	1.339	1.000	85	27.1	1.088	30	0.353
2	1,019	66.77	0.902	1.000	61	27.1	1.088	30	0.492
3	1,203	58.88	1.012	1.029	74	27.1	1.088	35	0.473
4	1,337	54.37	1.025	1.127	84	27.1	1.088	39	0.464
5	1,359	69.27	0.922	1.057	92	27.1	1.026	38	0.413
6	1,486	64.60	0.922	0.979	87	27.1	1.088	44	0.506
7	1,498	33.60	1.203	1.047	63	27.1	1.088	44	0.698
8	1,499	57.82	1.153	0.964	96	27.1	1.088	44	0.458
9	1,557	61.06	1.012	1.054	101	27.1	1.043	44	0.436
10	1,620	54.08	1.107	0.969	94	27.1	1.088	48	0.511
11	1,635	72.96	1.186	1.000	141	25.3	1.028	43	0.305
12	1,711	77.89	0.902	1.000	120	27.1	1.088	50	0.417
13	1,752	53.73	1.153	1.099	119	25.3	1.090	48	0.408
14	1,784	62.69	1.186	1.038	138	27.1	1.088	53	0.384
15	2,095	46.27	1.038	0.936	94	27.1	1.088	62	0.660
16	2,465	73.73	1.107	0.969	195	25.3	1.090	68	0.349
17	2,597	40.55	1.000	1.000	105	27.1	1.088	77	0.733
18	2,614	51.34	1.297	1.000	174	27.1	1.088	77	0.443
19	2,748	50.20	0.922	1.085	138	27.1	1.088	81	0.587
20	3,071	58.57	1.012	1.026	187	27.1	1.026	85	0.455
21	3,752	71.29	1.000	1.038	278	25.3	1.090	103	0.371
22	4,018	60.31	1.064	0.951	245	28.3	1.153	131	0.535
23	4,136	71.66	0.912	0.950	257	27.1	1.088	122	0.475
24	4,170	57.44	0.892	1.011	216	25.3	1.090	115	0.532
25	4,389	61.16	0.965	1.027	266	25.3	1.014	113	0.425

26.....	4,662	62.37	1.012	1.048	308	25.3	1.028	121	0.393
27.....	5,638	58.68	0.892	0.968	286	25.3	1.090	155	0.542
28.....	6,470	67.56	0.912	1.009	402	27.1	0.979	172	0.428
29.....	7,787	59.84	0.976	1.018	463	28.3	1.071	236	0.510
30.....	22,470	71.76	0.922	1.000	1,487	30.5	0.987	676	0.455
31.....	23,107	40.46	0.922	0.955	823	30.5	0.977	689	0.837
32.....	23,912	34.26	1.297	1.060	1,126	30.5	1.017	742	0.659
Unweighted ruble-dollar ratio									0.491
Value-weighted ruble-dollar ratio					8,405			4,415	0.525

[1] *Dodge Digest*, April 1972, pp. G401–G420. Construction volumes have been converted from cubic feet to cubic meters.
[2] *Ibid.* Total construction costs excluding the cost of built-in equipment are divided by the construction volume and multiplied by a constant—0.932—to eliminate air-conditioning.
[3] *Ibid.*, pp. O–V. The index for each city in 1970 based on New York = 100 is shifted to a base of 83 to account for regional differences.
[4] *Ibid.* The coefficient to adjust bid date dollars to 1970 is obtained by dividing the city index for 1970 by the city index for the bid date.
[5] Column (1) x column (2) x column (3) x column (4).
[6] *Sborniki, Budget Series*, no. 4, pp. 82–97.
[7] *Ibid.*
[8] Column (1) x column (6) x column (7).
[9] Column (8) ÷ column (5).

The US weights are derived from a sample of approximately 200 office buildings in the *Dodge Digest*. This sample includes more than $136 million worth of contract bids. Each structure is assigned to a group, depending on the number of stories, and the bid costs for each group are summed. This grouping provides the data for deriving a percentage distribution to use as weights.

The Soviet Union has not published data for office buildings distributed by number of stories as has been done for housing. Since the economics of construction in the USSR are similar for office buildings and apartments, the housing weights as measured by quantity are applied to office buildings. These weights are then adjusted to a value basis on the assumption that the sample average cost per cubic meter for each story varies in the same proportion as does actual average cost.

Ruble cost estimates are based on the same methodology as the *Dodge Digest* approach, but differences exist for the dollar methodology. The costs in the *Dodge Digest* are already adjusted to mid-1970 prices, with regional differences eliminated. US office buildings of average quality are always used. These buildings are grouped into three categories: walk-ups (1–3 stories), low-rise (1–4 stories), and high-rise (more than four stories). Only the low-rise are without air-conditioning, so the standard 6.8% correction is used in the other cases. Since two building categories overlap for one to three stories, the ratio for these levels represents the average of four ratios: two for walk-ups and two for low-rise. The basic costs of high-rise office buildings do not include interior partitions, so they must be added. Since finished gypsum board is a common Soviet wall material, it is used for the US costs at a rate of $1.80 per square foot of partition. With the quantity of interior walls assumed to be equal to one-third of total floorspace, the cost per square foot of floorspace is 60 cents; this amount, which is equivalent to $1.77 per cubic meter, is added to the basic cost. The data for individual observations are given in Table E-2.

Results

The results of the *Dodge Digest* approach appear in Table E-3. The unweighted and value-weighted ratios are 0.491 and 0.525, respectively. The coefficient of variation for the unweighted ratio is 24%; a 95% confidence interval encloses the mean in a range from 0.448 to 0.534. Testing the dispersion of the individual ruble-dollar ratios suggests they are distributed with a strong central tendency.* Since the unweighted ratio is less than the value-weighted one, this indicates the existence of a positive scale effect with the ruble-dollar ratio increasing with project size.

The ratio for the *Dodge Guide* approach is derived in Table E-4. The result—0.471—is substantially less than the result from the *Dodge Digest* approach. The Soviet-weighted ruble-dollar ratio is less than the US-weighted ratio because the Soviets perform better at their own construction mix than at the US mix. Thus, the lowest ruble-dollar ratio is for five-story buildings, which is their most frequent structural type. The ratios for three- and four-story structures are higher probably because they are five-story buildings redesigned for fewer stories, and the buildings are thus apparently stronger than necessary. The ruble-dollar ratio increases for buildings above five-stories because the United

*The chi-square test for central tendency results in a test value of 6.00. A value larger than 14.07 is needed to refute the assertion of a central tendency at 95% confidence.

Table E-2

Office Building Sample: Dodge Guide Approach

(1) Number of Stories	(2) Volume of Structure [1] (Cubic Meters)	(3) US Cost per Cubic Meter [2] (US $)	(4) Total US Cost [3] (Thousand 1970 US $)	(5) Soviet Cost per Cubic Meter [4] (Rubles)	(6) Total Soviet Cost [5] (Thousand 1970 Rubles)	(7) Ruble-Dollar Ratio [6]
1	657	71.40	46.9	29.5	19.4	0.414
1	3,285	79.76	262	29.5	97	0.370
1	6,570	51.48	338	29.5	194	0.574
1	22,993	46.40	1,067	28.0	644	0.604
Average	8,376	62.26	428	29.1	239	0.490
2	657	71.40	46.9	27.6	18.1	0.386
2	3,285	79.76	262	27.6	91	0.347
2	6,570	51.48	338	27.6	181	0.536
2	22,993	46.40	1,067	26.2	602	0.564
Average	8,376	62.26	428	27.2	223	0.458
3	657	71.40	46.9	30.9	20.3	0.433
3	3,285	79.76	262	32.6	107	0.408
3	6,570	51.48	338	30.9	203	0.601
3	22,993	46.40	1,067	31.0	713	0.668
Average	8,376	62.26	428	31.4	261	0.528
4	3,285	79.76	262	32.7	107	0.408
4	22,993	46.40	1,067	31.0	713	0.668
Average	13,139	63.08	664	31.8	410	0.538
5	26,280	81.09	2,131	31.0	815	0.382
5	45,985	67.62	3,110	31.0	1,426	0.459
Average	36,132	74.36	2,620	31.0	1,120	0.420
6	31,536	81.09	2,557	32.7	1,031	0.403
6	55,182	67.62	3,731	32.7	1,804	0.484
Average	43,359	74.36	3,144	32.7	1,418	0.444
7	36,792	81.09	2,983	32.7	1,203	0.403
7	64,379	67.62	4,353	32.7	2,105	0.484
Average	50,586	74.36	3,668	32.7	1,654	0.444
8	42,048	81.09	3,410	39.3	1,652	0.484
8	73,579	67.62	4,975	39.3	2,892	0. 581
Average	57,814	74.36	4,193	39.3	2,272	0.532
9	47,304	81.09	3,836	39.3	1,859	0.485
9	82,773	67.62	5,597	39.3	3,253	0.581
Average	65,038	74.36	4,716	39.3	2,556	0.533
10–14	n5,256 [7]	81.09	n426 [7]	44.2	n232 [7]	0.545
10–14	n9,197 [7]	67.62	n622 [7]	44.2	n407 [7]	0.654
Average	n7,226 [7]	74.36	n524 [7]	44.2	n320 [7]	0.600

[1] *Dodge Guide*, pp. (2–3)–(2–6). US costs given on a square foot basis are converted to cubic feet and subsequently to cubic meters with the assumption that the height of a story averages 11.6 feet.

[2] *Ibid.* Costs for buildings with air-conditioning receive a standard 6.8% deduction to eliminate the air-conditioning and conform to Soviet practice.

[3] Column (2) x column (3).

[4] *Sborniki, Budget Series*, no. 4, pp. 82–97.

[5] Column (2) x column (5).

[6] Column (6) ÷ column (4).

[7] The symbol "n" represents the number of stories where n has a range from 10 to 14.

Table E-3

Office Buildings Results: Dodge Digest Approach

	Average	Range	
		Minimum	Maximum
Volume (cubic meters)	4,705	1,014	23,912
Soviet cost (thousand rubles)	138	30	742
US cost (thousand US $)	263	61	1,487
Soviet-weighted cost (rubles per cubic meter)	29.3	25.7	32.6
US-weighted cost (dollars per cubic meter)	55.8	35.6	86.2
Unweighted ruble-dollar ratio	0.491	0.305	0.837
Value-weighted ruble-dollar ratio	0.525	....	....

Table E-4

Office Building Results: Dodge Guide Approach

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of Stories	Ruble-Dollar Ratio	Group Ruble-Dollar Ratio [1]	US Group Weights [2]	Composition of US-Weighted Ruble-Dollar Ratio [3]	Group Dollar-Ruble Ratio [4]	Soviet Group Weights [5]	Composition of Soviet-Weighted Dollar-Ruble Ratio [6]
1	0.490	0.474	0.341	0.162	2.110	0.121	0.255
2	0.458						
3	0.528	0.533	0.125	0.067	1.876	0.086	0.161
4	0.538						
5	0.420	0.420	0.305	0.128	2.381	0.572	1.362
6	0.444	0.486	0.032	0.016	2.058	0.183	0.377
7	0.444						
8	0.532						
9	0.533						
10	0.600	0.600	0.197	0.118	1.667	0.038	0.063
11	0.600						
12	0.600						
13	0.600						
14	0.600						
Average weighted ratios for office building				0.491			2.218

Geometric mean of US- and Soviet-weighted ruble-dollar ratios $= \left(0.491 \times \frac{1}{2.218}\right)^{1/2} = 0.471$

[1] Geometric mean of ruble-dollar ratio for each story group.

[2] *Dodge Digest*, pp. G40–G420.

[3] Column (3) x column (4).

[4] Reciprocal of column (3).

[5] Willard S. Smith, "Housing in the Soviet Union, Big Plans, Little Action," *Soviet Economic Prospects for the Seventies*, June 1973, p. 412.

[6] Column (6) x column (7). The Soviet-weighted ruble-dollar ratio equals 0.451.

States has a comparative advantage in tall buildings. Data in Table E-2 confirm the presence of the positive scale effect in that the ratio changes while the number of stories is held constant. This indicates that US industry obtains greater economies of scale for the construction of large office buildings than the USSR.

The reason for the difference between the ratios derived by the *Dodge Digest* and *Dodge Guide* approaches is easily explained, although it is unclear what to do about it. Table E-5 disaggregates the ratios of each approach by number of stories; the table stops at five stories because that is the tallest building in the *Dodge Digest* sample. The only gross discrepancy between the results of the two methodologies is for four-story buildings. Close examination reveals that the four-story buildings in the *Dodge Digest* sample are larger than the *Dodge Guide* sample. The already demonstrated positive scale effect explains why the ratios based on four-story *Dodge Digest* are larger; moreover, these ratios exert a large weight in the computation of the value-weighted ratio—i.e., more than 20% of the value of the entire sample.

The geometric mean of the value-weighted ratio in the *Dodge Digest* approach (0.525) and the US-weighted ratio in the *Dodge Guide* approach (0.491) provides the US-weighted ruble-dollar ratio (0.508). Likewise, the geometric mean of the US-weighted ratio and the Soviet-weighted ratio (0.451) equals 0.479 and is used for the office building ratio.

Table E-5

Comparison of Office Building Ruble-Dollar Ratios by Number of Stories

Number of Stories	Dodge Digest Approach		Dodge Guide Approach	
	Number of Observations	Ratio	Number of Observations	Ratio
1	19	0.494	4	0.490
2	8	0.415	4	0.458
3	2	0.523	4	0.528
4	2	0.748	2	0.538
5	1	0.455	2	0.420

APPENDIX F

SCHOOLS

The computation of a ruble-dollar ratio for school construction is similar to that used for office buildings. The *Dodge Digest* approach, which uses a sample of 23 elementary schools and 10 intermediate schools, results in a ratio representative of US construction. The *Dodge Guide* approach determines a ruble-dollar ratio by number of stories for each type of school and then combines them into an aggregate ratio based on estimated Soviet weights. In each approach, high school and college buildings are not considered because true international physical comparisons are difficult. Moreover, nonquantifiable socially determined esthetic tastes probably have a larger impact on the cost of these buildings than on elementary and intermediate school buildings.

The Dodge Digest Approach

The best quality Soviet schools are compared with the US sample. The building categories in the *Sborniki* are classified by number of stories. The 7%–9% more expensive enhanced (*povishennaya*) interior finish is used in preference to the simple (*prostaya*) finish. The basic Soviet costs are adjusted to incorporate the cost of installed boiler equipment, hot-water supply, and a ventilation system. The data for the US and Soviet estimates appear in Table F-1.

The US construction costs of these schools are adjusted to conform to Soviet practice. The cost of built-in equipment except boiler equipment is removed from the US costs. Only one of the elementary and eight of the intermediate schools are air-conditioned; in these cases the cost of air-conditioning is estimated and deducted from the total cost. The bid costs are adjusted to June 1970 dollars by the Dodge index of construction costs for the nearest major city and altered to 83% of New York City construction costs to eliminate regional variation.

The Dodge Guide Approach

The methodology of the *Dodge Guide* approach which uses Soviet weights results in a ratio more nearly representative of Soviet construction. The preponderance of US school construction is of one-story or at most two-story structures. On the other hand, a large proportion of Soviet school buildings are taller, mainly five-stories. Generally, US schools are built out and Soviet schools are built up. Since the ruble-dollar ratio depends partly on the number of stories, the *Dodge Digest* sample excludes construction that the Soviets perform best; this imparts an upward bias to the ratio.

The *Dodge Guide* approach partly avoids this problem. First, a ruble-dollar ratio for a given number of stories is calculated by using the arithmetic mean of the ruble-dollar ratio for the smallest and largest building in each category. These ratios are grouped by geometric means into a series of ratios compatible

[p. 48 blank]

Table F-1

School Sample: Dodge Digest Approach

Elementary School	(1) Volume of Structure [1] (Cubic Meters)	(2) Unadjusted US Cost per Cubic Meter [2] (US $)	(3) Territorial Adjustment [3] (Index)	(4) Conversion to Mid-1970 US $ [4] (Index)	(5) Adjusted Total US Cost [5] (Thousand 1970 US $)	(6) Soviet Cost per Cubic Meter [6] (Rubles)	(7) Total Soviet Cost [7] (Thousand 1970 Rubles)	(8) Ruble-Dollar Ratio [8]
1	3,094	60.12	0.915	1.000	170	24.6	76	0.447
2	4,420	48.57	0.923	1.051	208	24.6	109	0.524
3	4,528	37.32	1.178	1.092	217	24.6	111	0.512
4	8,297	59.30	0.940	1.000	462	25.2	209	0.452
5	8,495	55.92	1.202	0.865	494	24.6	209	0.423
6	8,820	50.23	0.958	1.064	452	25.7	227	0.502
7	9,045	34.38	1.181	1.064	391	25.9	234	0.598
8	9,770	30.50	1.040	1.038	322	25.9	253	0.786
9	10,432	43.14	0.958	1.064	459	26.0	271	0.590
10	10,612	54.00	1.147	0.988	649	24.4	259	0.399
11	13,370	42.41	0.936	1.297	688	26.9	360	0.523
12	13,451	52.64	0.912	0.965	623	26.9	362	0.581
13	13,887	51.70	1.028	0.874	645	27.0	375	0.581
14	14,583	41.49	1.184	0.933	668	25.4	370	0.554
15	15,089	32.47	1.186	1.064	618	27.4	413	0.668
16	15,978	36.05	0.979	0.922	520	27.7	443	0.852
17	16,367	58.90	1.157	0.874	975	27.8	455	0.467
18	17,943	44.70	1.010	0.988	800	28.3	508	0.635
19	18,473	33.94	0.938	1.000	588	28.4	525	0.893
20	20,068	42.31	1.157	0.922	906	26.1	524	0.578
21	21,522	61.52	1.155	0.988	1,511	27.6	594	0.393
22	16,004	42.43	1.181	1.297	1,040	27.7	443	0.426
23	33,726	47.44	1.065	0.922	1,571	27.6	931	0.593
Unweighted ruble-dollar ratio								0.564
Value-weighted ruble-dollar ratio					14,977		8,261	0.552

Intermediate School								
1.....	18,344	37.07	0.989	1.000	673	25.9	475	0.706
2.....	18,653	34.20	1.030	0.965	634	25.9	483	0.762
3.....	18,780	57.14	0.910	1.012	988	28.5	535	0.541
4.....	17,975	44.45	0.960	1.137	872	28.3	509	0.584
5.....	23,496	39.41	0.925	1.277	1,094	30.0	705	0.644
6.....	24,636	34.75	0.885	0.954	723	26.7	658	0.910
7.....	34,796	32.76	0.980	1.339	1,496	27.8	967	0.646
8.....	63,244	35.20	0.994	1.078	2,385	24.8	1,568	0.657
9.....	60,457	51.57	1.033	0.943	3,037	29.6	1,790	0.589
10.....	25,190	52.08	1.143	1.064	1,595	25.3	637	0.399
Unweighted ruble-dollar ratio								0.644
Value-weighted ruble-dollar ratio					13,497		8,327	0.617
Combined sample								
Unweighted ruble-dollar ratio								0.588
Value-weighted ruble-dollar ratio					28,474		16,588	0.583

[1] *Dodge Digest*, September 1972, pp. C101–114, C201–205, September 1968, pp. C101–118, C201–210. Construction volumes have been converted from cubic feet to cubic meters.
[2] *Ibid.* Total construction costs excluding the cost of built-in equipment are divided by construction volume.
[3] *Ibid.*, pp. O–V. The index for each city in 1970 based on New York = 100 is shifted to a base of 83 to account for regional differences.
[4] *Ibid.* The coefficient to adjust bid date dollars to 1970 is obtained by dividing the city index for 1970 by the city index for the bid date.
[5] Column (1) x column (2) x column (3) x column (4).
[6] *Sborniki, Budget Series*, no. 7, pp. 41–50, 63–72.
[7] Column (1) x column (6).
[8] Column (7) ÷ column (5).

with the estimated Soviet weights. The weights are derived by assuming that the distribution by number of stories is identical with that for apartment buildings of up to five-stories, although there are a negligible number of schools above five-stories. This quantity distribution is then adjusted to value weights by using average cost per cubic meter as is described in Appendix D.

The ruble costs are estimated the same way as in the *Dodge Guide* approach, but there is a difference in the dollar costing. When using the *Dodge Guide* for other forms of construction, average quality construction was always used, but the source reports only construction costs for good and excellent quality schools. A sample of the other categories of construction, however, reveals that average quality structures cost approximately 83% of good quality, so the US school costs are reduced to that percentage. As before, the US costs are automatically adjusted for regional and temporal differences. Moreover, the expense of air-conditioning has been eliminated from these costs. The data for this methodology are in Table F-2.

Results

Table F-3 contains the results of the *Dodge Digest* approach. The ruble-dollar ratios for elementary schools are less than the corresponding ratios for intermediate schools. The value-weighted ratio is less than the unweighted ratio for both types of school, although combining the two samples virtually eliminates the apparent scale effect. The coefficient of variation of these three samples ranges between 21% and 24%. Confidence intervals of 95% established around the unweighted ratios provide estimate ranges of the unweighted ratios of 0.506–0.622 for elementary schools, 0.547–0.741 for intermediate schools, and 0.539–0.637 for the combined sample. Testing the dispersion of the individual ratios suggests an existing central tendency for the samples of both the elementary schools and combined data, although the size of the sample for intermediate schools is too limited for meaningful conclusions.*

The *Dodge Guide* ratios are computed with Soviet weights in Table F-4. The geometric mean of the *Dodge Guide* ratios for elementary and intermediate schools provides that approach's overall school ratio. These ratios are substantially lower than the results of the other methodology which accords with the expectation that the Soviet-weighted ratio would be lower than one weighted by US construction. A test was performed to ascertain that the difference between the results of the two approaches is really a product of the weighting systems. This test used the *Dodge Guide* ratios for number of stories and weighted them with US weights for the same number of stories as derived from a large *Dodge Digest* sample. These US-weighted ratios—0.588 and 0.606 for elementary and intermediate schools, respectively—are nearly equal to the value-weighted ratios from the *Dodge Digest* approach. Additional corroboration is provided by the decline of the ruble-dollar ratio as the number of stories increases for both school types.

Table F-2 shows that even though the ruble-dollar ratio diminishes as the number of stories are increased, the ratio increases with the size of the structure.

*The chi-square test for central tendency gives value of 6.83 and 4.75 for elementary schools and the combined sample, respectively; a test value above 14.07 would have required serious examination of the central tendency assertion. A test value for intermediate schools would have dubious validity because of the limited sample size.

Table F-2

School Sample: Dodge Guide Approach

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Number of Stories	Volume of Structure [1] (Cubic Meters)	US Cost per Cubic Meter [2] (US $)	Total US Cost [3] (Thousand 1970 US $)	Soviet Cost per Cubic Meter [4] (Rubles)	Total Soviet Cost [5] (Thousand 1970 Rubles)	Ruble-Dollar Ratio [6]
Elementary schools						
1	3,681	54.16	199	24.6	91	0.457
1	25,768	44.01	1,134	30.4	783	0.690
Average	14,724	49.08	666	27.5	437	0.573
2	3,681	54.16	199	24.0	88	0.442
2	25,768	44.01	1,134	25.5	657	0.579
Average	14,724	49.08	666	24.8	372	0.510
3	3,681	54.16	199	23.4	86	0.432
3	25,768	44.01	1,134	23.9	616	0.543
Average	14,724	49.08	666	23.6	351	0.487
4	3,681	54.16	199	23.0	85	0.427
4	25,768	44.01	1,134	23.2	598	0.527
Average	14,724	49.08	666	23.1	342	0.477
5	3,681	54.16	199	22.7	84	0.422
5	25,768	44.01	1,134	23.0	593	0.523
Average	14,724	49.08	666	22.8	338	0.472
Intermediate schools						
1	22,087	54.70	1,208	26.4	583	0.483
1	58,899	40.72	2,398	30.8	1,814	0.756
Average	40,493	47.71	1,803	28.6	1,198	0.620
2	22,087	54.70	1,208	25.1	554	0.459
2	58,899	40.72	2,398	29.4	1,732	0.722
Average	40,493	47.71	1,803	27.2	1,143	0.590
3	22,087	54.70	1,208	23.8	526	0.435
3	58,899	40.72	2,398	24.7	1,455	0.607
Average	40,493	47.71	1,803	24.2	990	0.521
4	22,087	54.70	1,208	23.2	512	0.424
4	58,899	40.72	2,398	23.7	1,396	0.582
Average	40,493	47.71	1,803	23.4	954	0.503
5	22,087	54.70	1,208	23.0	508	0.421
5	58,899	40.72	2,398	23.5	1,384	0.577
Average	40,493	47.71	1,803	23.2	946	0.499

[1] *Dodge Guide*, pp. 5–4. US costs given on a square foot basis are converted to cubic feet and subsequently cubic meters with the assumption that the story height averages 13 feet.

[2] *Ibid.* Costs are presented for only good or better quality schools, so the quality is reduced to average by a multiplicative correction factor of 0.83.

[3] Column (2) x column (3).

[4] *Sborniki, Budget Series*, no. 7, pp. 41–50, 63–72.

[5] Column (2) x column (5).

[6] Column (6) ÷ column (4).

This partly conflicts with the result of the other approach, which indicates, although ambiguously, the opposite scale effect. It is more plausible, however, for the ruble-dollar ratio to increase with school size when the number of stories is held constant. Larger buildings cannot derive as much from the Soviets' advantages of the industrialization of construction and the standardization of plans because they are less homogeneous. This view is even partly supported by the *Dodge Digest* (in addition to the *Dodge Guide*) results where the intermediate schools have a higher ratio than the elementary ones. In both cases the intermediate schools represented by each sample are larger structures than the average elementary school.

The geometric mean of the value-weighted *Dodge Digest* ratio and the *Dodge Guide* ratio is used for the final school ratios. These aggregate ratios are:

Elementary schools—0.517
Intermediate schools—0.565
All schools—0.540

Table F-3

School Results: Dodge Digest Approach

	Average	Range	
		Minimum	Maximum
A. *Elementary* (sample size = 23)			
Volume (cubic meters)	13,390	3,094	33,726
Soviet cost (thousand rubles)	359	76	931
US cost (thousand US $)	651	170	1,571
Soviet-weighted cost (rubles per cubic meter)	26.8	24.4	28.4
US-weighted cost (dollars per cubic meter)	48.6	31.8	70.2
Unweighted ruble-dollar ratios	0.564	0.393	0.893
Value-weighted ruble-dollar ratio	0.552	....	....
B. *Intermediate* (sample size = 10)			
Volume (cubic meters)	30,557	17,975	63,244
Soviet cost (thousand rubles)	833	475	1,790
US cost (thousand US $)	1,350	634	3,037
Soviet-weighted cost (rubles per cubic meter)	27.3	24.8	30.0
US-weighted cost (dollars per cubic meter)	44.2	29.3	63.3
Unweighted ruble-dollar ratios	0.644	0.399	0.910
Value-weighted ruble-dollar ratio	0.617	....	....
C. *Combined sample* (sample size = 33)			
Volume (cubic meters)	18,592	3,094	63,244
Soviet cost (thousand rubles)	503	76	1,790
US cost (thousand US $)	863	170	3,037
Soviet-weighted cost (rubles per cubic meter)	27.0	24.4	30.0
US-weighted cost (dollars per cubic meter)	46.4	31.8	70.2
Unweighted ruble-dollar ratios	0.588	0.393	0.910
Value-weighted ruble-dollar ratio	0.583	....	....

Table F-4

School Results: Dodge Guide Approach

(1) Number of Stories	(2) Ruble-Dollar Ratio	(3) Group Ruble-Dollar Ratio [1]	(4) Soviet Group Weights [2]	(5) Group Dollar-Ruble Ratio [3]	(6) Composition of Soviet-Weighted Dollar-Ruble Ratio [4]
Elementary					
1	0.573	0.541	0.188	1.848	0.347
2	0.510				
3	0.487	0.482	0.107	2.075	0.222
4	0.477				
5	0.472	0.472	0.705	2.119	1.494
Average weighted ratios for elementary schools					2.063
Intermediate					
1	0.620	0.605	0.196	1.653	0.324
2	0.590				
3	0.521	0.512	0.106	1.953	0.207
4	0.503				
5	0.499	0.499	0.698	2.004	1.399
Average weighted ratios for intermediate schools					1.930
Average Soviet-weighted ratios for schools = $(2.063 \times 1.930)^{1/2}$					

[1] Geometric mean of ruble-dollar ratio for each group.

[2] Willard S. Smith, "Housing in the Soviet Union: Big Plans, Little Action," *Soviet Economic Prospects for the Seventies*, June 1973, p. 412.

[3] Reciprocal of column (3).

[4] Column (4) x column (5). The ruble-dollar ratios are 0.485, 0.518, and 0.501 for elementary, intermediate, and all schools, respectively.

APPENDIX G

INDUSTRY

The Approach

Two different samples were collected for derivation of a ruble-dollar ratio for construction projects in industry. The first sample, which was taken from the *Dodge Digest*, contains 27 observations. Since this sample is composed primarily of light industrial projects, a second sample was collected from private industry sources to represent construction in heavy industry. Neither sample is particularly representative of its segment of industry, but most of the differences in industrial investment projects are in terms of equipment and not construction. Thus, a valid ratio for industrial construction need not be totally representative of all industrial activity.

The data for the two samples, which are denoted as the "light industry" and the "heavy industry" samples, are presented in Tables G-1 and G-2. The dollar costs are adjusted to eliminate any air-conditioning and built-in equipment, where required to parallel Soviet construction practices. Also, the dollar costs are converted to mid-1970 dollars and to the costs of an average US location. For the heavy industry sample, only the dates for the completion of construction were available; this does not correspond to the practice elsewhere, because bid-date dollars were adjusted to 1970 prices. To reconcile the data, an arbitrary bid date of two years prior to completion of construction was assumed and the dollars adjusted accordingly. The two-year lag is conservative because a longer lag would result in a lower ruble-dollar ratio.

The Soviet and US projects are compared on the basis of size and similarity of construction. This matching does *not* imply, however, that the Soviet plant has the same production capacity as its US counterpart. Ruble-dollar ratios depending on the productivity of labor, equipment, and other inputs which are beyond the scope of this study would be needed for that kind of comparison.

Results

Table G-3 summarizes the raw data and the resultant ratios. The unweighted ruble-dollar ratios for light industry and heavy industry are 0.584 and 0.519, respectively, and the coefficients of variation are 23% and 19%. The establishment of a 95% confidence interval around the mean produces a wide-interval estimate because of the large dispersion of ratios for both samples and the very small sample size for heavy industry. The interval of the estimate suggests a ruble-dollar ratio between 0.533 and 0.637 for light industry and between 0.423 and 0.619 for heavy industry. The large degree of overlap between the two confidence intervals and the small sample for heavy industry negate any conclusion that the light industry ratio differs from the heavy industry ratio. Testing the dispersion of the individual ruble-dollar ratios indicates the existence of a

[p. 56 blank]

Table G-1

Light Industry Sample

	(1) Type of Structure	(2) Volume of Structure [1] (Cubic Meters)	(3) Unadjusted US Cost per Cubic Meter [2] (US $)	(4) Territorial Adjustment [3] (Index)	(5) Conversion to Mid-1970 US $ [4] (Index)	(6) Adjusted Total US Cost [5] (Thousand 1970 US $)	(7) Unadjusted Soviet Cost per Cubic Meter [6] (Rubles)	(8) Total Soviet Cost [7] (Thousand 1970 Rubles)	(9) Ruble-Dollar Ratio [8]
1	Cold storage plant	1,509	60.30	1.361	1.175	146	46.1	70	0.479
2	Meat processing plant	2,752	63.59	1.012	1.025	182	38.8	107	0.588
3	Meat processing plant	3,251	45.52	1.092	1.178	190	23.0	75	0.395
4	Tool manufacturing	1,529	41.20	0.943	1.052	62	14.7	22	0.355
5	Electrical component manufacturing	2,934	16.36	1.012	1.180	57	13.8	40	0.702
6	Electric appliance manufacturing	16,826	13.19	1.137	1.180	298	10.6	178	0.597
7	Container manufacturing	95,145	19.44	0.912	1.181	1,992	9.7	923	0.463
8	Molding plant	138,581	17.78	0.965	1.048	2,492	15.7	2,176	0.873
9	Knitwear plant	14,826	22.60	0.943	1.118	353	14.4	213	0.603
10	Textile plant	16,311	16.92	1.339	1.205	445	14.3	233	0.524
11	Clothing manufacturing plant	50,920	16.79	1.078	1.039	958	14.5	738	0.770
12	Shoe manufacturing plant	22,597	19.65	1.186	1.241	654	18.6	420	0.642
13	Shoe manufacturing plant	39,400	22.18	0.943	1.161	957	18.6	733	0.766
14	Printing plant	5,631	43.33	0.988	1.067	257	24.2	136	0.529
15	Printing plant	6,142	38.10	1.025	1.045	251	24.2	149	0.594
16	Newspaper printing plant	7,910	26.30	1.107	1.155	266	24.2	191	0.718
17	Newspaper plant	18,818	47.88	0.988	1.205	1,073	18.9	356	0.332
18	Newspaper building	20,710	20.52	1.153	1.173	575	18.9	391	0.680
19	Factory	3,517	19.62	0.943	1.236	80	13.4	47	0.588
20	Manufacturing plant	3,562	21.06	1.107	1.092	91	13.4	48	0.527
21	Manufacturing plant	3,964	19.68	1.012	1.117	88	13.4	53	0.602
22	Industrial building	5,823	27.13	0.933	1.202	177	12.6	73	0.412
23	Manufacturing building	11,044	24.72	0.933	1.178	300	16.1	178	0.593

24	Chemical manufacturing plant	25,726	33.12	0.965	1.245	1,024	30.0	772	0.754
25	Printing building	26,000	15.23	1.012	1.180	473	10.6	276	0.584
26	Manufacturing building	31,950	24.85	0.943	1.193	893	16.1	514	0.576
27	Manufacturing plant	53,216	17.53	0.954	1.269	1,129	11.3	601	0.532
Unweighted ruble-dollar ratio									0.584
Value-weighted ruble-dollar ratio						15,463		9,713	0.628

[1] *Dodge Digest*, March 1970, pp. G501–515, and April 1972, pp. G501–512. Construction volumes have been converted from cubic feet to cubic meters.
[2] *Ibid.* Total construction costs excluding the cost of built-in equipment and air-conditioning are divided by the construction volume.
[3] *Ibid.*, pp. O–V. The index for each city in 1970 based on New York = 100 is shifted to a base of 83 to account for regional differences.
[4] *Ibid.* The coefficient to adjust bid date dollars to 1970 is obtained by dividing the city index for 1970 by the city index for the bid date.
[5] Column (2) x column (3) x column (4) x column (5).
[6] *Sborniki, Investment Series:*

Structure	Source		Structure	Source	
	Volume	Page		Volume	Page
1	33	62	15	15	7
2	33	62	16	15	7
3	11	17	17	15	8
4	18	7	18	15	8
5	7	47	19	18	6
6	18	6	20	18	6
7	7	15	21	18	6
8	7	29	22	18	6
9	14	76	23	7	11
10	14	22	24	7	28
11	14	10	25	18	6
12	14	87	26	7	11
13	14	87	27	7	14
14	15	7			

[7] Column (2) x column (7).
[8] Column (8) ÷ column (6).

Table G-2

Heavy Industry Sample

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Type of Structure	Volume of Structure [1] (Cubic Meters)	Unadjusted US Cost per Cubic Meter [2] (US $)	Territorial Adjustment [3] (Index)	Conversion to Mid-1970 US $ [4] (Index)	Adjusted Total US Cost [5] (Thousand 1970 US $)	Unadjusted Soviet Cost per Cubic Meter [6] (Rubles)	Total Soviet Cost [7] (Thousand 1970 Rubles)	Ruble-Dollar Ratio [8]
1. Continuous furnace building	76,456	11.57	0.922	1.272	1,037	6.8	520	0.501
2. Mill building and motor room building	521,569	12.90	0.922	1.272	7,891	8.2	4,277	0.542
3. Processing building	302,709	8.05	0.922	1.272	2,858	5.0	1,514	0.530
4. BOF shop	844,130	25.83	0.922	1.157	23,259	17.1	14,435	0.621
5. Blast furnace cast house	45,307	64.62	0.922	1.157	3,123	27.7	1,255	0.402
Unweighted ruble-dollar ratio								0.519
Value-weighted ruble-dollar ratio					38,168		22,001	0.576

[1] Private industry.

[2] *Ibid.* Total construction costs excluding the cost of built-in equipment and air-conditioning are divided by the construction volume.

[3] *Ibid.*, pp. O–V. The index for each city in 1970 based on New York = 100 is shifted to a base of 83 to account for regional differences.

[4] *Ibid.* The coefficient to adjust bid date dollars to 1970 is obtained by dividing the city index for 1970 by the city index for the bid date.

[5] Column (2) x column (3) x column (4) x column (5).

[6] *Sborniki, Investment Series:*

Structure	Source: Volume	Source: Page
1	1	61
2	1	65
3	1	66
4	1	58
5	1	14

[7] Column (2) x column (7).

[8] Column (8) ÷ column (6).

Table G-3

Industry

	Average	Range	
		Minimum	Maximum
A. *Light Industry* (sample size = 27)			
Volume (cubic meters)	23,355	1,509	138,581
Soviet cost (thousand rubles)	360	22	2,176
US cost (thousand US $)	573	57	2,492
Soviet-weighted cost (rubles per cubic meter)	15.4	9.7	46.4
US-weighted cost (dollars per cubic meter)	24.5	17.7	96.8
Unweighted ruble-dollar ratios	0.584	0.332	0.873
Value-weighted ruble-dollar ratio	0.628	....	....
B. *Heavy Industry* (sample size = 5)			
Volume (cubic meters)	358,034	45,307	844,130
Soviet cost (thousand rubles)	4,400	520	14,435
US cost (thousand US $)	7,634	1,037	23,259
Soviet-weighted cost (rubles per cubic meter)	12.3	5.0	27.7
US-weighted cost (dollars per cubic meter)	21.3	9.4	68.9
Unweighted ruble-dollar ratios	0.519	0.402	0.621
Value-weighted ruble-dollar ratio	0.576	....	....

fairly strong central tendency for light industry. The heavy industry sample is too small to conduct any tests.*

The value-weighted ratios are 0.628 for light industry and 0.576 for heavy industry. In each sample the value-weighted ratio exceeds the unweighted ratio by more than 7½%. This accords with the expectation that the ruble-dollar ratio tends to increase as the project size increases. The amount of customization required in the larger projects prevents the USSR from taking advantage of standardization and other cost-saving practices in construction. The geometric mean of the two value-weighted ratios—0.601—is used as the aggregate industrial construction ratio.

*The chi-square test for central tendency results in a test value of 1.17. A value in excess of 12.83 would have been needed to refute the assertion of a central tendency.

APPENDIX H

TRANSPORTATION

Three types of transportation construction are selected for this study: roads, airfields, and railroads. A somewhat different methodology from that previously described for other types of construction must be employed because both the *Dodge Digest* and *Dodge Guide* are devoid of US cost data for transportation construction. Two alternative sources—the *1972 Building Cost File: Eastern Edition* and the *Building Construction Cost Data, 1972*—are used instead to cost various roads, airfields, and railroads described in the *Sborniki*. A major drawback of this approach is that these alternative sources present the cost data solely on the basis of a unit of construction—cost per kilometer of railroad or cost per square meter of airfield—instead of the cost for a total project. Thus, it is impossible to determine the effect of project scale on ruble-dollar ratios; for example, differences cannot be discerned between the ruble-dollar ratio for a short stretch of road and that for a major interstate highway system.

The Approach

Four types of road construction are included in the transportation sample—concrete, asphaltic-concrete, bitumen-paved, and gravel. The road costs used for the ruble-dollar ratio include expenditures on the road surface, normal excavation, drainage, and grading. Excluded from the costs are site preparation, removal of existing structures, relocation of utilities and other roads, and other indirect construction costs.

The technical specifications for the four roads derived from the *Sborniki* are presented in Table H-1. The ruble values published in these *Sborniki* tables contain items in addition to the cost of earthwork and pavement such as small bridges. Fortunately, an available table yields the percentage distribution of cost by construction element. By using this information, it is possible to eliminate the cost of these extraneous elements.

The dollar expenditure for these four roads is estimated from data contained in the *Building Cost File*. The dollar costs in this source are given in 1972 prices and represent construction costs in New York City. To render these dollar amounts compatible to the values of other types of construction in this study, the costs are converted to 1970 dollars by a multiplicative coefficient of 0.884 and to an average US regional cost by a coefficient of 0.83.*

The amount of earthwork per kilometer—in terms of both physical volume and US costs—is equal for all of the roads except gravel. The total cost of earthwork for the three paved roads comprises the sum of expenditures for excavation,

*The time coefficient is the ratio of the Department of Commerce composite cost index for June 1970 and June 1972. See page 6 in the main text for discussion of the regional adjustment.

[p. 62 blank]

Table H-1

Road Construction Ruble-Dollar Ratio

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	US Cost per Kilometer of Road (1970 US $)			Soviet Cost per Kilometer of Road (1970 Rubles)			Ruble-Dollar Ratio		
Road Description [1]	Earthwork [2]	Pavement [3]	Total [4]	Earthwork [5]	Pavement [6]	Total [7]	Earthwork [8]	Pavement [9]	Total [10]
1. Concrete Road (7 meters wide, 18 cm thick concrete, 20,600 cubic meters of earthwork).	28,579	100,213	128,792	38,280	58,080	96,360	1.339	0.580	0.748
2. Asphaltic Concrete Road (7 meters wide, 9 cm thick asphaltic concrete, 25 cm gravel base, 20,600 cubic meters of earthwork).....	28,579	72,313	100,892	35,432	53,457	88,889	1.240	0.739	0.881
3. Bitumen Paved Road (7 meters wide, 6 cm thick bitumen coat, bitumen shot 6 cm deep, 25 cm gravel base, 20,600 cubic meters of earthwork).....	28,579	77,468	106,047	35,344	44,556	79,900	1.237	0.575	0.753
4. Gravel Road (4.5 meters wide, 20 cm thick of gravel, 7,500 cubic meters of earthwork).	9,433	7,037	16,470	5,976	6,806	12,782	0.634	0.967	0.776
Average.....	23,792	64,258	88,050	28,758	40,725	69,483	1.112	0.715	0.790

[1] *Sborniki, Budget Series*, no. 23, pp. 6, 9.
[2] *1972 Building Cost File: Eastern Edition*, Construction Publishing Company, N.Y., pp. 17–18.
[3] *Ibid.*, pp. 328–329.
[4] Column (2) + column (3).
[5] *Sborniki, Budget Series*, no. 23, pp. 6, 9, 15.
[6] *Ibid.*
[7] Column (5) + column (6).
[8] Column (5) ÷ column (2).
[9] Column (6) ÷ column (3).
[10] Column (7) ÷ column (4).

95% compaction by a sheepsfoot roller, and the dumping and spreading of fill and gravel materials in 15.24-centimeter layers. The quantity of excavation equals the stated volume of earthwork, i.e., 20,600 cubic meters; a medium clay composition is assumed for the excavated material. Moreover, one-half of this volume is actually dumped, spread, and compacted. The quantity of earthwork for the gravel road is much smaller than the others; this is largely attributable to the comparative narrowness of that road.

Costing the pavement portion of the construction in dollars depends on the nature of the surface. All the road shoulders are considered as gravel or crushed stone except that dirt shoulders are assumed for the gravel road. The cost of the asphaltic-concrete road represents the sum of expenditures for crushed stone for the road base and shoulders, a nine-centimeter-thick leveling course of asphaltic-

concrete, and a six-centimeter-deep shot of bitumen paving below the surface. The bitumen paved road has crushed stone like the asphaltic-concrete, a six-centimeter-deep penetration by the bitumen paving, and a six-centimeter-thick layer of bitumen paving on top. The gravel road has a 14-centimeter-thick loose course of gravel and a six-centimeter top layer.

Estimation of the cost per square meter of runways on airfields—takeoff and landing strips—is quite direct. Various combinations of runway thickness are arbitrarily selected and then costed in both rubles and dollars. Since the physical volume of earthwork represented in the *Sborniki* costs is unknown, the construction estimates contain only the cost of the concrete surface and a sand and gravel base. Again, the dollar costs are adjusted to an average location, 1970 base, using the same coefficients as for roads.

The estimated costs of railroad construction per kilometer of track is the sum of expenditures for ties, ballast, and the rails themselves. Since there are several different possible rail sizes, depending on the proposed traffic density of the railroad, ruble-dollar ratios are derived for various sizes. Moreover, ratios are computed for both lines with wooden ties and concrete ties.

The quantity of ballast and sand base that should be used in one kilometer of single-track Soviet railroad is reported in *Spravochnik po zheleznodorozhnomu stroitel'stvu* (Handbook for Railroad Construction). The costs of these two items are readily obtained from the appropriate *Sborniki* and the *Building Cost File*. The dollar amounts are adjusted to a 1970 average cost basis as elsewhere.

Direct comparisons between three types of rails are feasible. These are 90-pound, 100-pound, and 130-pound rails for the United States and R-43, R-50, and R-65 rails for the USSR.* A ruble cost for R-43 rail with concrete ties cannot be determined. Apparently the Soviets deem R-43 rail as too light for heavy traffic and, therefore, not worth the additional expenditure for concrete ties. In costing the rails, 25-meter lengths are assumed. Frequently, for any given rail weight, a choice exists as to how the rails are connected; when this occurs, the average of the options for that rail size is used.

The *Building Cost File* includes the cost of wooden ties in the cost of the rail. This differs from the *Sborniki* in which the cost of the ties is estimated separately. The Soviet source presents an option of three alternative frequencies of ties—i.e., 1,600, 1,840, and 2,000 ties per kilometer. These three frequencies have been matched with R-43, R-50, and R-65 rails, respectively, on the judgment that the heavier rail requires more ties.

Costing the concrete tie railroads in rubles uses the identical procedure as for wooden ties. Since the *Building Cost File* incorporates wooden ties in the cost of the rail, their cost must be deducted and the cost of the concrete ties added. This is accomplished by using *Building Construction Cost Data, 1972*, which compares the cost of individual concrete and wood ties. The difference between these two unit prices represents the additional cost of concrete ties. This differential is augmented by 25%, which is that source's suggested markup for the overhead and profit already included in the *Building Cost File*, and is added to the cost for the appropriate wooden-tie railroad.

*The Soviet rail number is approximately the weight of one meter of rail as measured in kilograms.

Results

The results of the transportation construction study are presented in Table H-1 for roads, in Table H-2 for airfields, and in Table H-3 for railroads. The sample ruble-dollar ratios for roads range between 0.748 and 0.881 and average 0.790. As expected, the ratio for concrete roads is lowest—perhaps reflecting the wide use of concrete in construction in the USSR. Moreover, the average ratio for earthwork is substantially higher than the ratio for pavement, which supports the contention that Soviet excavation and other earthwork is relatively inefficient because of the low capacity and poor quality of Soviet construction machinery.

The airfield ratios range from 0.670 to 0.729 and average 0.695. These ratios are lower than the ratios for roads—even those for concrete roads. In part, the ratios are lower because earthwork is excluded from the airfield construction estimates, eliminating from consideration a kind of construction in which the USSR is at a relative disadvantage. Finally, no relation is evident between airfield runway thickness and the size of the ruble-dollar ratio.

The ruble-dollar ratios for railroad construction vary between 0.761 and 0.891 and average 0.836. The ratio rises as heavier rail is used. The effect of the use of concrete ties on the ratio is uncertain, however, because the ratio is lower for heavy-duty R-65 rail with concrete ties and higher for medium duty R-50 rail with concrete ties. Perhaps the railroad ruble-dollar ratio is higher than other forms of transportation construction because roads and airfields require less sophisticated construction techniques than railroads, for which precision and quality are essential.

Table H-2

Airfield Construction Ruble-Dollar Ratio

Description of Pavement	(1) US Cost per Square Meter [1] (1970 US $)	(2) Soviet Cost per Square Meter [2] (1970 Rubles)	(3) Ruble-Dollar Ratio [3]
15.24 cm thick concrete	12.78	8.56	0.670
20.00 cm thick concrete	15.88	10.88	0.685
25.40 cm thick concrete	19.07	13.58	0.712
30.48 cm thick concrete	22.32	16.28	0.729
38.10 cm thick concrete	29.29	19.93	0.680
Average	19.87	13.85	0.695

[1] *1972 Building Cost File: Eastern Edition*, pp. 328–329.
[2] *Sborniki, Investment Series*, no. 24, p. 12.
[3] Column (2) ÷ column (1).

Table H-3

Railroad Construction

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	US Cost per Kilometer of Track (1970 US $)				Soviet Cost per Kilometer of Track (1970 Rubles)				
Track Description [1]	Stone Ballast [2]	Sand Base [3]	Rail and Ties [4]	Total [5]	Stone Ballast [6]	Sand Base [7]	Rail and Ties [8]	Total [9]	Ruble-Dollar Ratio [10]
Wood ties									
90 lb US rail vs R-43 Soviet rail	14,431	4,623	58,280	77,334	16,698	4,418	37,760	58,876	0.761
100 lb US rail vs R-50 Soviet rail	14,431	4,623	65,360	84,414	16,698	4,418	48,942	70,058	0.830
130 lb US rail vs R-65 Soviet rail	14,431	4,623	74,367	93,421	16,698	4,418	62,100	83,216	0.891
Average	14,431	4,623	66,002	85,056	16,698	4,418	49,601	70,717	0.827
Concrete ties									
100 lb US rail vs R-50 Soviet rail	14,431	4,623	89,765	108,819	17,549	5,015	68,562	91,126	0.837
130 lb US rail vs R-65 Soviet rail	14,431	4,623	97,576	116,630	17,549	5,015	77,750	100,314	0.860
Average	14,431	4,623	93,670	112,724	17,549	5,015	73,156	95,720	0.849
Average [11]	14,431	4,623	77,070	96,124	17,038	4,657	59,023	80,718	0.836

[1] The *Building Cost File* contains construction costs for US 90-, 100-, and 130-pound rail. The numbers refer to the weight of one yard of rail. These weights converted to a metric basis are 44.65, 49.61, and 64.49 kilograms per meter, respectively. The Soviet rails closest to these magnitudes are R-43, R-50, and R-65 which weigh 44.65, 51.64, and 64.64 kilograms per meter, respectively. Sources: *Spravochnik po zheleznodorozhnomu stroitel'stvu* (*Handbook for Railroad Construction*), p. 154, and *Zheleznyye dorogi obshchiy kurs* (*Railroads: A General Course*), p. 46.

[2] The quantity of crushed stone ballast used for a kilometer of track is 1,518 cubic meters. Source: *Spravochnik, op. cit.*, p. 159, and *Cost File, op. cit.*, p. 339.

[3] The quantity of sand used as base for the ballast prism per kilometer is 796 cubic meters. Sources: *Spravochnik, op. cit.*, p. 159, and *Cost File, op. cit.*, p. 339.

[4] *Ibid.*

[5] Column (2) + column (3) + column (4).

[6] *Sborniki, Investment Series*, no. 21, p. 175. Also see note 2.

[7] *Ibid.* Also see note 3.

[8] *Ibid.*, pp. 176–182, and *Building Construction Cost Data, 1972*, Robert Snow Mearis Company, Inc., pp. 29, 185.

[9] Column (6) + column (7) + column (8).

[10] Column (9) ÷ column (5).

[11] This is the unweighted average of each specific track description, i.e., the mean of IA, IB, IC, IIA, and IIB.

APPENDIX I

WEIGHTED CONSTRUCTION RUBLE-DOLLAR RATIOS

Table I-1

1970 US-Weighted Construction Ruble-Dollar Ratio

Category	Weights	Ruble-Dollar Ratio	Weighted Ruble-Dollar Ratio
Hospitals[1]	0.048	0.568	0.027
Housing	0.471	0.620	0.292
Commercial[2]	0.140	0.508	0.071
Schools	0.093	0.583	0.054
Industrial	0.101	0.601	0.061
Highways and streets	0.143	0.790	0.113
Railroad	0.004	0.836	0.003
US-weighted ratio	....	....	0.621

[1] The geometric mean of the US-weighted housing, office building, and school ratio is used instead of the computed but discredited hospital ratio.

[2] The office building ratio is used for the commercial category.

Table I-2

1970 Soviet-Weighted Construction Ruble-Dollar Ratio

Category	Weights	Ruble-Dollar Ratio	Dollar-Ruble Ratio	Weighted Dollar-Ruble Ratio
Industry	0.362	0.601	1.664	0.602
Transportation and communications except railroad[1]	0.060	0.741	1.350	0.081
Railroad	0.026	0.836	1.196	0.031
Housing	0.270	0.494	2.024	0.546
Trade and communal enterprises, forestry enterprises, and institutions of science, culture, art, education, and health[2]	0.282	0.475	2.105	0.594
Soviet-weighted ratio	....	....	....	1.854

[1] The geometric mean of road and airfield ratios is used for this class of construction.

[2] Presumably forestry construction is a negligible portion of this category. The geometric mean of the office building and school ratios is arbitrarily assigned to this group.

Table I-3

Adjusted 1970 US-Weighted Construction Ruble-Dollar Ratio

Category	Weights	Ruble-Dollar Ratio	Weighted Ruble-Dollar Ratio
Hospitals	0.048	0.682	0.033
Housing	0.471	0.744	0.350
Commercial	0.140	0.610	0.085
Schools	0.093	0.700	0.065
Industrial	0.101	0.721	0.073
Highways and streets	0.143	0.948	0.136
Railroad	0.004	1.003	0.004
Adjusted US-weighted ratio	....	....	0.746

Table I-4

Adjusted 1970 Soviet-Weighted Construction Ruble-Dollar Ratio

Category	Weights	Ruble-Dollar Ratio	Dollar-Ruble Ratio	Weighted Dollar-Ruble Ratio
Industry	0.362	0.721	1.387	0.502
Transportation and communications except railroad	0.060	0.889	1.125	0.068
Railroad	0.026	1.003	0.997	0.026
Housing	0.270	0.593	1.686	0.455
Trade and communal enterprises, forestry enterprises, and institutions of science, culture, art, education, and health	0.282	0.570	1.754	0.495
Adjusted Soviet-weighted ratio	....	....	....	1.546